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Modern Lithology

Illustrated and Defined

by

ERNEST HOWARD ADYE

W. & A. K. JOHNSTON LIMITED
EDINBURGH & LONDON

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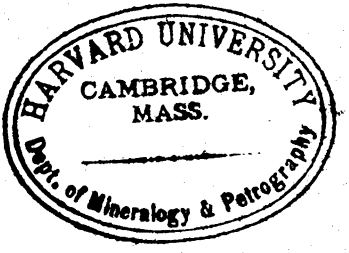

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Modern Lithology

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FOR THE USE OF
UNIVERSITY, TECHNICAL AND CIVIL-SERVICE
STUDENTS

BY

ERNEST HOWARD ADYE

W. & A. K. JOHNSTON LIMITED
EDINBURGH AND LONDON

1907

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FOREWORD.

ROCK textures nowadays require to be resolved under varying powers of the microscope in order to reveal the true significance, mutual relations and paragenesis of their mineral constituents. In these senses, the microscopic study of rocks may correctly claim the title chosen for this little work, which is intended to simplify matters for students who are ambitious enough to excel in a branch of science which is daily growing stronger by reason of extending research, its fascinating attributes, and intrinsic commercial coupled with scientific worth.

The frontispiece and the figure of Picritic-Serpentine, Plate IX., Fig. 4, are from the author's brush, taken through the *camera lucida* from exceptionally perfect typical sections. All the other drawings were made from actual microscopic preparations, in the publishers' ateliers. They are vast improvements on ordinary etchings or photo-micrographs, and being projected in slightly diagrammatic style ought to enable students to instantly identify mineral species and organic remains, inasmuch as both colours and contours are limned with sufficient fidelity.

Considerable pains have been taken to render the text terse yet adequate, by affording details concerning the coloured illustrations, and conforming to the classification most in vogue at the universities of to-day as concisely as possible.

Students of modern lithology are presumed to possess a

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general knowledge of elementary physics, — particularly of crystallography and chemistry. In subordination to these subjects, they should endeavour to master the principles of biology, and become fairly familiar with the rudiments of systematic botany and zoology. So many cheap yet excellent text-books on these branches of learning are now published that it would be invidious, and indeed superfluous, to name any of these in particular.

Introductory matter concerning lithology, *per se*, may also be dispensed with in this place, because most of the current handbooks are well provided with such information. Field work; the megascopic determination of specimens; the registration of topographical details and geological horizon; the methods of levigation, washing, decantation and preparation of particles, as well as the slitting, reduction and mounting of slices for microscopical investigation are fully dealt with in many of the works and papers enumerated on the subjoined list.

It is expected that the glossary appended to this little work will be found specially serviceable to students.

Reading about rocks is good; studying figures, and especially correctly coloured figures, in conjunction with the text is better; but the examination of actual specimens by the side of both drawings and text is best of all.

E. H. A.

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FRONTISPIECE.

PICRITE.
Inchcolm, Firth of Forth.

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FRONTISPIECE.

Picrite, Inchcolm, Firth of Forth.—Sections of this specimen present surpassingly beautiful pictures under the microscope. Some of these are accurately depicted in this frontispiece; but, in order to a correct appreciation of these presentments, the mineralogical characters of the rock require to be defined as follows: The dominant constituent is olivine in fairly idiomorphic forms. It is never quite fresh, but shows every stage of alteration into serpentine. Next in abundance comes a brownish-pink, appreciably pleochroic augite, which often shows hour-glass structure, and is frequently intergrown with or altered into brown marginal hornblende. The other original constituents, in order of importance, are basaltic hornblende, biotite, plagioclastic felspar of a variety approaching anorthite, ilmenite, magnetite and apatite. The secondary substances represented are pseudomorphs of serpentine after olivine; interstitial viridite with stellate chloritic spots; grey granular patches denoting decayed felspar; amorphous separated and derived calcite, sundry zeolites, a little deep brown picotite, and secondary magnetite grains in the olivine meshwork and spicules of ilmenite at the margins of some of the augites.

Upper left circle, × 18.—Shows an idiomorphic central crystal of olivine, with fresh kernels of the mineral enmeshed in irregular fissures filled with serpentine and displaying several black separated forms of magnetite.

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Other olivine crystals are shown cut by the circumference, and may be identified by their yellowish-green anastomosing meshes and colourless kernels of the fresh mineral which show shagreened surfaces and polarise in vivid hues of crimson, green, etc. These olivines are pœcilitic in relation to the comparatively fresh crystals of grey felspar which have aggregated around them with a sheaf-like tendency. Under polarised light the crystals of felspar on the left-hand boundary shows twin lamellation very clearly, and the extinction on both sides of the twinning plane gives angles of over 50°. This, together with the fact that the felspar is prone to decompose and be replaced by zeolites, suffices to determine its species as anorthite.

Upper right circle, × 25.—Depicts an extraordinarily good example of a cross section through a skeletal aggregate of titaniferous iron, not unlike a Chinese uncial in black, inclosed within a large much fractured plate of brownish-pink augite. The latter is manifestly darker in colour towards the left boundary, and it may also be noticed that the partially serpentinised olivines, with yellow borders and fissures, have by their expansion due to alteration, caused the inclosing plate of augite to give way in directions radially developed from the olivines. The green shows a patch of interstitial alteration products (*viridite*).

Lower left circle, × 20.—Here, there are two large sub-idiomorphic plates of brownish-pink augite, inclosing small crystals of partially altered olivine in pœcilitic fashion; while their margins are encased with an intergrowth of black iron ore, composed of densely crowded spicules, granules and microlites of magnetite and pro-

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bably also of ilmenite in association. Towards the lower right margin of the inferior crystal of augite may be seen a ruddy-brown patch of secondary or intergrown hornblende, which upon careful scrutiny reveals prismatic cleavages, and also sends tongues of its substance into the augite. The medium-sized six-sided yellow crystal to the left of the augite is a pseudomorph after olivine; while immediately above there is a large somewhat corroded black plate of titaniferous iron. The grey patch to its left represents part of a large interstitial crystal of felspar; while on the right and between the two large augites green, brown, and grey decomposition products may give the reactions of serpentine, chlorite, calcite, minute scales of biotite, limonitic stains, and probably (at the extreme mid-boundary to the right) a crumbling black-grey patch of ilmenite showing signs of leucoxenic degeneration.

Lower right circle.—The left half of this figure is magnified 25 diameters, to show a particularly well-developed crystal of original basaltic hornblende of a light brown colour towards the centre. It is seen to envelop a border of bright green viridite around a triangular nucleus of grey decomposing matter (amorphous calcite), while the body of the crystal is invaded on either side by much metamorphosed olivines of a yellow colour shot with green. The crystal section when revolved under light from a single nicol is seen to be intensely pleochroic; and, if restored by projection would afford an excellent example of a section perpendicular to the vertical axis showing two clinopinacoidal and four prismatic planes. The brownish-pink augite to the left is margined with a ruddy-brown

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border which exhibits a change of cleavage angles from the 87° of augite to the 124° of hornblende, and therefore evidences a uralitic change. The right semicircle in this picture is magnified 120 diameters to show laminated cinnamon-coloured strongly pleochroic biotite with frayed edges; and two sections of glassy, highly refringent crystals of apatite,—the longitudinal section displaying the characteristic transverse fracture, and the cross section exhibiting a clear hexagonal outline. The green parts represent complex decomposition products, which, for the sake of convenience, may be designated viridite.

Central circle, × 25, between crossed nicols. This picture affords an exceptionally fine example of the *hour-glass structure* which may frequently be seen in the augites of this rock. The large fairly idiomorphic crystal of augite occupies nearly the whole of the field, and its long axis has been placed at right angles to the short diagonal of the polarising prism, in order to reveal the hour-glass structure to the best advantage. Only part of the large crystal of augite is shown, and the hour-glass structure may be seen in light blue, clearly defined from the outer dark blue on either side which forms the remainder of the augite. As commonly happens, this crystal of augite incloses four small crystals of olivine in pœcilitic fashion. The two uppermost are illuminated in dark and light neutral tints, giving the characteristic polarisation effects of serpentine, into which they have been almost entirely converted; but the two lower olivines show green and red granular colouration, thereby denoting the presence of kernels of the fresh, unaltered mineral. It will also

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be noticed that the augite is pervaded by sinuous bands and patches of yellow and red. These define the positions of the larger fissures in the crystal which have become filled with decomposition products. On the extreme right the boundary of the augite shows a marginal growth of hornblende, in which the prismatic cleavage is clearly exhibited, and also part of a black hexagonal plate of titaniferous iron.

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PLATE I.

Fig. 1. Obsidian, Mexico, × 20.—A yellowish-brown transparent volcanic glass, showing darker and lighter bands of microlites and trichites, the linear arrangement of these incipient crystals being due to the flow of the mass during consolidation. This is a typical obsidian or glassy rhyolite free from phenocrysts, but crowded with crystallites of the nature of globulites, margarites, trichites, longulites and microlites. The last-named crystallitic bodies are built up of aggregates of the minuter forms previously named; while some of them have a brush-like form (scopulites), others develop swallow-tail terminations, and yet others assume the shapes and give the optical reactions proper to the minerals of which they are diminutive representatives, viz., felspar, augite, hornblende, tourmaline, zircon, mica, specular iron and magnetite.

The lowermost band of crystallites in the figure depicts some of the better defined microlites of the rock. Upon careful scrutiny, small elongated prisms of felspar, sometimes with bifid ends, may be detected, along with much contorted trichites and yellowish-red hexagonal tabular crystules of specular iron, and scales of reddish-brown magnesian mica. These last may be recognised by their strong dichroism when cut transversely or obliquely to their basal planes.

Fig. 2. Pitchstone, Corriegills, Arran, Scotland,

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Fig. 1. OBSIDIAN.
Mexico, × 20.

Fig. 2. PITCHSTONE.
Corriegills, × 20.

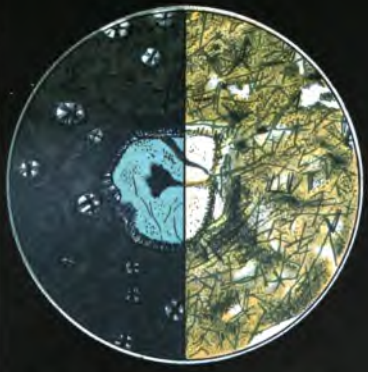

Fig. 3. PITCHSTONE.
Meissen, Saxony, × 20.

Fig. 4. PITCHSTONE.
Corriegills, × 20.

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× 20.—Viewed by ordinary transmitted light to show a central clear and colourless crystal of sanidine felspar, cut obliquely, and bristling with acicular microlites radially disposed from its margins. This phenocryst of sanidine is surrounded by a greenish-grey groundmass of isotropic glass devitrified by myriads of microlites, the larger of which are surrounded by clear spaces, or "courts of crystallisation." The more minute microlites devitrify all intermediate parts of the glassy base. Even with such a low power as 20 diameters, the larger microlites display surpassingly delicate fern-frond forms. Some of these in longitudinal sections are bilaterally symmetrical and tend to indicate "flow-structure"; others are radially arranged into stellate groups, while yet a third series appear in whorls or tufts.

Under higher powers of the microscope (from 100 to 500 diameters), the true nature of these microlites can be readily resolved. They will be found to consist of acicular "midribs" diminishing from thicker ragged "petiolar" ends to a pointed apical extremity. From these midribs plumose pinnæ are given off in more or less complete closely-set whorls at irregular intervals in diminishing series from the base to the extremity of the frondoid microlite, as shown on a small scale by many of the elongated microlites in the figure. Some of these larger microlites are in the form of plain needles, without pinnæ, while transverse sections often show cross pieces with tufted ends. When some of the larger needles are cut transversely they are seen under high powers to be skeleton-crystals usually deficient along one margin and give upon measurement the angle 124°, while their maximum extinction in the prismatic

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zone is 15°. These microlites are therefore referable to hornblende, probably of the variety actinolite. The smaller microlites which devitrify the interspaces between the courts of crystallisation surrounding the larger compound microlites are mostly in the form of small rods,—"bacterolites,"—and when cut transversely appear as specks. It is therefore reasonable to suppose that the dendritic microlites took origin from the bacterolites, leaving clear encircling zones; while the bacterolites themselves most likely are the nascent derivatives of the magma.

Chemical analysis shows that this pitchstone is closely allied to granite. In addition to phenocrysts of sanidine the rock contains other large crystals of anorthoclase, blebs of quartz, and occasional crystals of augite. These, however, are not shown in the figure; while it is interesting to note that the quartz is often encysted in an envelope of hyalite diversified by segregations and nuclei of tridymite.

Fig. 3. Pitchstone, Meissen, Saxony, × 20.—*Right semicircle* shows part of a central crystal of sanidine, bristled at its margins with radially disposed microlites of hornblende. The ground-mass consists of a yellowish-brown isotropic glass, crowded with needles of hornblende (actinolite) and very minute bacterolites, which devitrify the intermediate matrix. Every here and there, there are clear spaces surrounding sundry spherulites of fairly large size. These peculiar structures consist of radiating fibrils of felspar bound together by quartz.

Left semicircle.—To show the rock structure under polarised light. The central crystal of sanidine is

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shown well illuminated, and contains a large inclusion of isotropic glass which is, of course, quite dark. The glassy base is also extinguished, but the microlites of of hornblende are just visible, while the spherulites show characteristic black crosses, which are caused by extinction in those fibrils which lie nearly parallel to one of the cross-wires.

The Meissen so-called "pitchstones" are in reality rhyolites or acid lavas, of Permian age, of the obsidian type. The cryptocrystalline character of these rocks appears to have resulted through devitrification of the original glassy ground-mass along perlitic fissures.

Fig. 4. Pitchstone, Corriegills, Arran, Scotland, × 20. Under crossed nicols. — The central crystal of sanidine is brightly illuminated. The greenish microlites become barely visible, doubtless by reason of the diffraction of light from the minute trichites which compose the tufts; but the midribs and the minuter bacterolites extinguish with the isotropic glassy magma.

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PLATE II.

Fig. 1. Perlite, × 20.—*Left semicircle.* Typically developed in the Hlinik valley, near Schemnitz, Hungary, and at Sandy Braes, Co. Antrim, Ireland. The glassy base of the rock, discoloured by yellowish-brown streaks of iron oxide, shows sinuous flow-lines traversed by a system of curvilinear perlitic cracks. These delicate rifts originated by contraction during the consolidation of the rock-mass, dividing it into numerous globules, which, by reason of their flaws exhibit a nacreous or pearly lustre.

Right semicircle. **Pumice,** × 20. — Of completely glassy texture, this figure shows by difference of depths in colour the characteristics of *pumiceous structure.* The upper and lower portions are literally riddled with elongated steam-vesicles, while the central portion remains intact but is considerably twisted and contorted, thereby giving rise to the phenomenon which causes *strain* structure.

Fig. 2. Tachylite, × 15.—The purely vitreous type of basaltic rocks termed *tachylite* occurs, apart from lapilli and other ejectamenta, in very limited distribution; as when basalt has been rapidly cooled by contact. It develops a thin selvage of dark glass, which may also sometimes be formed superficially on lava flows. Under the microscope, tachylite appears as a dark brown or yellow glass, charged with black specks of magnetite. The separated iron ore may segregate into *globulites*,

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Fig. 1. PERLITE AND PUMICE.
Sandy Braes, Antrim, etc., × 20.

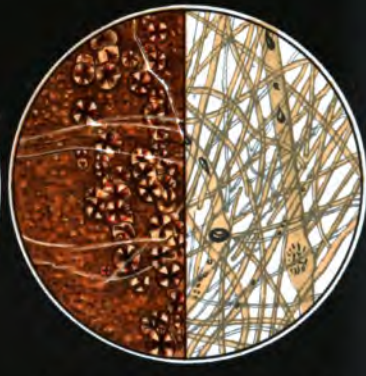

Fig. 2. TACHYLITE, × 15, AND PÉLÉ'S HAIR, × 20.
Pélé's Hair from Kilauea.

Fig. 3. VARIOLITE.
Loch Scridain, Mull, × 20.

Fig. 4. LIMBURGITE.
Stopfelskuppe, Thuringia, × 20.

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sometimes so closely set as to render the glass opaque. At other times these separations collect into *cumulites* or cloudy patches, or form *trichites* or *crystallites* of minute size; while yet again, as in the *left-hand semicircle* of the figure, spherulitic structures composed of radially disposed particles, which show crosses, are developed. Occasionally, perlitic cracks also obtain, but these are not so frequently met with as in the acid glasses (obsidians).

Pélé's Hair, Kilauea, Hawaii, × 20, is typically shown by the *right-hand semicircle* of this figure. Sir Archibald Geikie, in his comprehensive *Text-book of Geology*, observes: "The varying degrees of liquidity are manifested in a characteristic way on the surface of lava. Thus, in the great lava-pools of Hawaii, the rock exhibits a remarkable liquidity, throwing up fountains of molten rock to a height of 300 feet or more. During the ebullition in the crater-pools jets and driblets a quarter of an inch in diameter are tossed up, and, falling back on one another, make 'a column of hardened tears of lava,' one of which was found to have attained a height of 40 feet; while, in other places, the jets thrown up and blown aside by the wind give rise to long threads of glass which lie thickly together like mown grass, and are known by the natives under the name of *Pélé's Hair*, after one of their divinities . . . Pélé's Hair is sometimes carried by wind from the summit of Mauna Loa to Hilo, a distance of 35 miles!" Under the microscope, as shown by the illustration, these slender yellowish-brown glassy threads occasionally bulge out at places which become the seat of deposits of separated black iron ore (magnetite), and

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commonly terminate in fused knobs and nodules not unlike the strings produced artificially in some blast-furnace slags. The glass is, of course, isotropic.

Fig. 3. Variolite, Loch Scridain, Mull, × 20.—When tachylites or basaltic glasses develop radiate aggregates of felspar microlites or fibrous arrangements which answer to the spherulites of acid rocks they are classed under the type *variolite*. The example here shown exhibits fine fan-like groupings of these fibres, developed at places into sheaves and regular, radiate, almost spherulitic growths, with but very little interstitial glassy base. The rock shows a very wide range of structure under the microscope, from mere fan-like groupings of the felspar microlites or sheaf-like forms with a lath-shaped nucleus to extremely regular, radiate, spherulitic growths. These again, may be so closely packed together as to constitute the entire portion of a rock, or they may be disposed in bands, or occur here and there among cumulites, globulites, and the like, in the isotropic glassy matrix.

Fig. 4. Limburgite, Stopfelskuppe, near Eisenach, Thuringia, × 20.—The name *Limburgite* was applied by Rosenbusch to the magma-basalts of Bôricky on account of their being typically developed at Limburg near the Kaiserstuhl. They are defined as being ultrabasic lavas, rich in olivine and augite, but free from felspar; and it is assumed that the crystallisation of the rock-mass must have been arrested, both in the *intratelluric* and *effusive* periods, prior to the separation of the felspar. In the figure, one-half of which,—the *left-hand semicircle*,—is shown under crossed nicols, a large somewhat corroded, yet idiomorphic crystal of olivine,

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with its irregular fissures and shagreened surface is centrally placed. The portion of this crystal in the polarised field is blue with red and yellow fissures, along which metamorphism into serpentine has supervened; the other half of the same crystal viewed by ordinary transmitted light is practically colourless and traversed by greenish-grey fissures of metamorphism. Other olivines, to the right, are irregular and fragmentary, but the smaller phenocrysts of almost colourless and sometimes greenish augites, show fairly idiomorphic contours,—elongated hexagons and rhombs. The same forms, on the left-hand side, in polarised light, are differently tinted according to the relation of the crystal sections to the planes of polarisation. Part of a large phenocryst of olivine is shown brilliantly red with yellow fissures towards the bottom of the field, while immediately above is a six-sided section of augite similarly coloured. All these phenocrysts of olivine and augite are seen with higher powers (from 100 to 500 diameters) to be studded in a brown isotropic glass, checkered with a second crop of small augites and generally disseminated granules of magnetite.

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PLATE III.

Fig. 1. Spherulitic Rhyolite, Hungary, × 20.—Shown by the *left-hand semicircle.* Von Richthofen in the year 1860 first used the name *rhyolite* to denote a group of rocks frequently characterised by flow structure. About the same time Roth gave the name of *liparite* to similarly constituted rocks, which were found typically developed in the Lipari Islands. In modern lithology, the rhyolites are defined as the volcanic equivalents of the granites and elvans, and like the latter are essentially acid, and in most cases possessed of free silica in the form of quartz. The example here figured shows a devitrified ground-mass, in which tolerably large spherulites encroaching on each other are clearly depicted, the upper and lower spherulites showing that their outward extension has been effected by more than one stage of growth. On closer examination the spherulites are seen to be composed of radially disposed fibres of felspar bound together by clear silica, and the ground-mass intervening may also be resolved into an ultra-microscopic admixture of felspar and quartz.

The *right-hand semicircle* in this figure shows another more advanced phase of rhyolitic structure in a *liparite* from Hlinik, Hungary, where a rich variety of these rocks is developed in the tertiary volcanic formations of the district. The glassy siliceo-felsitic base in this instance shows manifest flow-structure, with specks of black opaque iron ore (magnetite). The phenocrysts

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Fig. 1. SPHERULITIC RHYOLITE AND LIPARITE.
Both from Hungary, × 20.

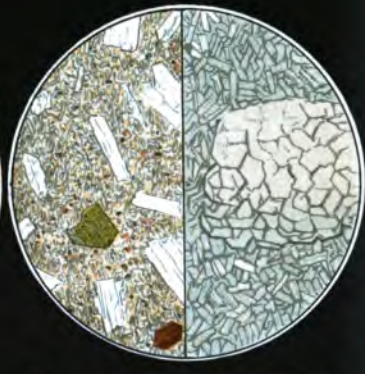

Fig. 2. TRACHYTE AND TRIDYMITE-TRACHYTE.
Wolkenburg and New Zealand, × 20.

Fig. 3. QUARTZ-FELSITE.
Vosges, France, × 20.

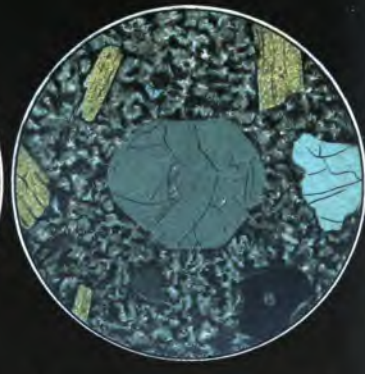

Fig. 4. QUARTZ-FELSITE.
Vosges, France, × 20.

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in this magma are dihexahedra of clear quartz, often corroded and exhibiting inlets from the ground-mass; a centrally situated colourless elongated crystal of soda-felspar with a habit similar to sanidine (potash-felspar), and two brown crystals of biotite (ferro-magnesian mica),—the upper a hexagonal flake and the lower a lath-shaped lamellated section. There is also a little apatite in this specimen, which, however, requires a higher power for its revelation.

Fig. 2. Trachyte, The Wolkenburg, Siebengebirge, × 20. — The trachytes were so-called by Haüy, by reason of their rough aspect in hand specimens. Modern lithologists, however, have retained the name to denote those volcanic lavas, which, not quite so acid as their allies,—the rhyolites,—are possessed of fully as much and oftentimes more of the alkalies. The specimen here illustrated by the *left-hand semicircle* is a fairly typical example, showing in the constitution of its practically holocrystalline matrix the characteristic *trachytic structure.* This consists essentially of lath-shaped felspar microlites showing a disposition to fluxional arrangement, and diversified throughout by black granules of magnetite, which under careful examination with condensed reflected light display the metallic-blue glancing colour so characteristic of that mineral. Little or no isotropic glass is revealed, even with high powers, and perlitic cracks are absent. The phenocrysts shown in the figure comprise colourless fissured columnar and tabular crystals of sanidine felspar, the one situated midway, at the left-hand boundary, showing traces of twinning on the Carlsbad type. The larger colourless phenocrysts, some of which

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show zonary banding and indications of multiple twinning, are oligoclase felspar. There is also a phenocryst of dirty green irregularly-shaped hornblende, showing prismatic cleavage-lines intersecting at an angle of 124°, and another brown hexagonal flake of biotite at the lowermost part of the field, which, unlike that mineral in this and the generality of trachytes, shows no signs of resorption.

The *right-hand semicircle* in this figure depicts the section of a **Tridymite Trachyte** from New Zealand, also magnified 20 diameters. In this, the holocrystalline ground-mass is composed entirely of stout and short crystules of felspar, constituting the structure defined by Rosenbusch as *orthophyric*. The silica in this uncommon rock has segregated into a mass, centralised in the figure, of six-sided colourless tablets of tridymite, which are resolved under crossed nicols into a number of depolarising areas exhibiting dark and light banding.

Fig. 3. Quartz-Felsite (*Argilophyre de Rupt*), Vosges, France, × 20.—The term *felsite* has been very laxly employed by petrographers to designate not only rocks of hypabyssal origin (the acid intrusives), but also to include many intermediate as well as acid volcanic rocks, notably, those belonging to the rhyolite group. The example here illustrated is of the last-named variety. It is essentially constituted by a cryptocrystalline ground-mass of *felsitic matter*, *i.e.*, an aggregate of quartz and felspar studded with porphyritic crystals of the same minerals. A large central much corroded crystal of clear quartz is shown with its characteristic strings of inclusions partially enveloping a

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diverticulum from the felsitic base and also inclosing a portion thereof in form of a so-called "negative crystal." The felspar phenocrysts are shown as elongated sections exhibiting zonary banding, and are of the variety oligoclase, which gives low extinction angles, not exceeding 7°. It is surmised that this particular rock was evolved from a flow of rhyolitic lava, which subsequently became cryptocrystalline, by the gradual devitrification of its glassy base.

Fig. 4. Quartz-Felsite (*Argilophyre de Rupt*), Vosges, France, × 20.—This figure shows another portion of the rock described above, under parallel, polarised light. The centre of the figure is occupied by a slightly rounded idiomorphic phenocryst of quartz, which, together with another irregular section of the same mineral, on the right-hand side, shows neutral interference tints, thereby indicating that the section must have been tolerably thin. When too thick, quartz-slices polarise in vivid colours. Another irregular crystal of quartz, with an inclosure of felsitic matter taking the form of a negative crystal, is shown in a position of extinction at the bottom of the field towards the right-hand side. The elongated felspar crystals show traces of polysynthetic twinning, while the felsitic matrix is fitfully illuminated, according to the relative placement of its particles, which may or may not happen to be in positions of extinction.

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PLATE IV.

Fig. 1. Felsite, × 20.—Although from an unknown locality, the rock from which this figure was taken is noteworthy on account of the absence of quartz phenocrysts. The ground-mass consists of an intimate admixture of quartz and felspar, in which are imbedded large, much fissured, tabular crystals of colourless sanidine felspar, often twinned on the Carlsbad type, and greenish-brown pleochroic biotite, both in hexagonal flakes and blade-like sections, which denote that the rock probably formed the marginal part of an intrusive mass.

Fig. 2. Felsite, × 20, to show another portion of the same slide from which the preceding picture was taken, but now under parallel polarised light. The ground-mass remains practically obscure, except for glimmerings of light, showing various interference tints, which are admitted through those portions of the felsitic matter which are not in positions of extinction. There is a large tabular twin of sanidine in the centre of the field, with three smaller sections of the same mineral adnate, while the other phenocrysts of sanidine are also shown in relief by lighter or darker neutral tints. It is just possible that the striated crystal forming the apex of the central phenocryst is part of a crystal of oligoclase felspar, while the laminated brightly coloured laths show the positions of the biotite phenocrysts.

Fig. 3. Dacite, Hungary, × 20.—Modern lithologists

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Fig. 1. FELSITE.
Ordinary Light, × 20.

Fig. 2. FELSITE.
Polarised Light, × 20.

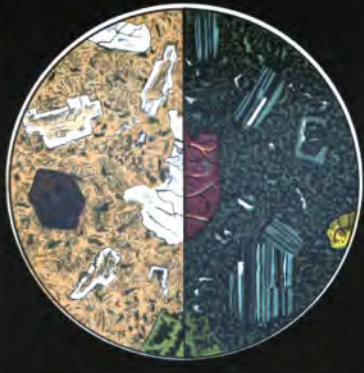

Fig. 3. DACITE.
Hungary, × 20.

Fig. 4. HORNBLENDE-ANDESITE.
Wolkenburg, × 20.

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have agreed to group all lavas of *intermediate* composition, other than trachytes and phonolites, under the comprehensive name of *Andesites*, but having found a limited number of kindred stones in the more acid division of the group, in the district of Dacia in Transylvania, Stache distinguished these quartz-bearing andesites by the now universally acknowledged name of *Dacites*. The *left-hand semicircle* of the figure here shown, exhibits a cryptocrystalline ground-mass; in which, however, a tendency to the development of microlitic laths of felspar is apparent. This is viewed under ordinary transmitted light, but the *right-hand semicircle*, under crossed nicols, shows that this ground-mass is, to some extent, composed of isotropic glass. Some of the darkened portions, however, are due to anisotropic particles lying in positions of extinction. Quartz phenocrysts are represented by a large, central, much corroded crystal, with strings of inclusions; a clear crystal with rounded angles at the upper apex of the left semicircle, and part of a faintly lemon-coloured, somewhat idiomorphic form intersected by the circumference on the right-hand side. Under ordinary light the felspar crystals are seen to be clearly zoned, and represent a variety of andesine more basic at the centres and acid at their boundaries. Polarised light (on the right) shows the plagioclastic albite lamellation of these felspars, which are also occasionally twinned on the Carlsbad type. At the lower end of the dividing diameter there is a section of part of a crystal of hornblende undergoing chloritic change with separations of magnetite in black patches, while submeridionally situated on the extreme left is a hexagonal

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section of brown hornblende exhibiting a resorption rim.

Fig. 4. Hornblende-Andesite, Wolkenburg, Siebengebirge, × 20.—In the tertiary volcanic district of the Siebengebirge, near Bonn, the hornblende-andesite of the Wolkenburg has long posed as a type for lithological students. The figure shows a ground-mass of the typical trachytic type already described, with phenocrysts of colourless andesine, and of two out of the three ferro-magnesian minerals,—hornblende, biotite, and augite. The hornblende, which is the dominant mineral of this last-named group, is represented by a fine, centrally placed, deep-brown hexagonal section, incised at its bottom boundary, and shows the phenomenon of resorption with the utmost clearness. Another incomplete crystal of hornblende of similar characteristics lies immediately above, to the right. It is part of a cross section which would show, upon complete projection, two clinopinacoidal and four prismatic planes, while its cleavage lines are clearly seen to intersect at an angle of 124° 30′. No biotite is shown in this figure, but in other parts of the slide it is seen in good phenocrysts of a dark-brown hue with resorption borders. At the right-hand bottom of the figure is an elongated crystal of green augite, which does not show any pleochroism when revolved under a single nicol. A little magnetite in black specks also obtains, and minute prisms and needles of clear colourless apatite occur in the portion of andesine depicted at the top left-hand side of the figure.

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Fig. 1. ALTERED ANDESITE AND PYROXENE-ANDESITE.
Meissen and Bohemia, × 15.

Fig. 2. ENSTATITE-LAMPROPHYRE.
Weinheim, Baden, × 15.

Fig. 3. PORPHYRITIC BASALT.
Lion's Haunch, Arthur's Seat, × 15.

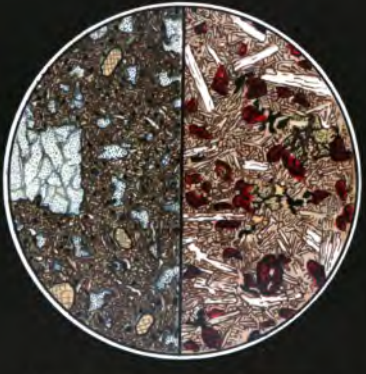

Fig. 4. OLIVINE-BASALTS.
Thuringia and Squire's Hill, × 20.

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PLATE V.

Fig. 1. Altered Andesite (*Porphyrite*), Meissen Saxony, × 15. — *Left-hand semicircle.* This figure shows a number of very large phenocrysts of plagioclastic felspar, which, instead of being fresh and glassy, have undergone kaolinisation to such an extent as to appear quite turbid. The laminated large crystals of dark mica (biotite) are also much altered; while the single section of brown hornblende shows signs of resorption. All these crystals are embedded in a ground-mass which, probably, was once glassy, but has undergone devitrification to such an extent as to exhibit a dull stony appearance.

The *right-hand semicircle*, also magnified 15 diameters, shows the structure of a very beautiful **Pyroxene-Andesite** from Bohemia. Here the ground-mass consists of a dark brown vitreous base, carrying a crop of minute felspars and allotriomorphic grains of augite, with sprinklings of octahedra and granules of magnetite. Three phenocrysts are shown of rhombic pyroxene, plentifully studded with magnetite. These show idiomorphic outlines, in which the pinacoid faces are more strongly developed than the prism, so that the cross sections show squares or parallelograms with truncated corners in contradistinction to the regular octagons of common augite. The grey fibrous patch at the top represents an infiltration of some zeolite, while the

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striated uncoloured body towards the centre, shows the twinned lamellæ of a particle of secondary calcite.

Fig. 2. Enstatite-Lamprophyre, Weinheim, Baden, × 15—Von Gümbel introduced the name *lamprophyre* in describing the mica-traps of the Fichtelgebirge, and the name has now been retained to designate a small group of rocks of intermediate composition which occur as small dykes and veins, but are not associated with tuffs. In the example here shown a base of pink orthoclase felspar is shown which exhibits the ultra-microscopic structure of that mineral. The colourless, much cracked and clear crystals are enstatite, a cross section of which appears in form of a square with truncated corners. One of the crystals of pyroxene, which is intersected by the circumference, shows its interior completely changed into green chlorite. The brown crystals represent two generations of biotite in large and small flakes respectively, the majority of which are distinctly laminated; while some of them, notably a dark brown somewhat contorted flake, at the left-hand side, intersected by the equator, shows two inclusions of apatite. The black squares and grains indicate the precise positions of magnetite crystals, which are fairly abundant in this specimen. Lamprophyres usually hold an abundance of carbonate of lime, which when not clearly manifested in sections under the microscope, is easily demonstrated by the effervescence which follows upon a slice of rock being etched with acid.

Fig. 3. Porphyritic Basalt, The Lion's Haunch, Arthur's Seat, Edinburgh, × 15.—The general characteristics of this thoroughly typical rock are well

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displayed by the figure, which shows a granular groundmass studded with porphyritic crystals of reddish-brown augite; shagreened olivine, with borders and fissures of yellowish-green serpentine; and clear crystals of plagioclase felspar, often zoned, and clouded within by numerous inclusions. A large six-sided section of augite is shown at the upper right-hand side of the figure, exhibiting irregular, thick and branching cracks; while near the diametric margin of the left-hand side an eight-sided, slightly zoned cross section of a smaller phenocryst of augite is depicted, showing cleavage angles of 87°. Many of the phenocrysts of augite in this rock are zoned, and some of the largest of them measure fully one-eighth of an inch. The zonary structure is due to slight variations in the extinction angles of different peripheral layers. The olivine phenocrysts are of various sizes, some of them being very large. Three examples are shown in the figure,—at the top, centre, and bottom respectively. The crystals show fairly fresh kernels of the mineral, with characteristically rough or shagreened surfaces; while their boundaries and network of fissures are invariably the seats of alteration into yellow and green serpentine, accompanied by separations of magnetite in spots and strings of diminutive grains. Some of the smaller crystals of olivine are completely metamorphosed into fibrous serpentine, which gives feeble bluish-grey and neutral interference tints under crossed nicols. The phenocrysts of clear, colourless felspar often measure one-quarter of an inch long, are well striated on the basal plane, and repeatedly twinned on the albite type. Their high extinction

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angles show that they are allied to anorthite,—probably bytownite. Many of these felspars are zoned, as shown in the figure, while some of them exhibit completely clouded cores, with inclusions, indicating phases of degradation.

The ground-mass requires powers of 100 to 500 diameters for its satisfactory resolution. It will then be revealed that only a trace of the original glassy isotropic magma persists in the form of a brownish or greenish-grey often devitrified interstitial base, which admits of being best studied in the larger felspar inclusions. A second crop of plagioclase felspar plays the *rôle* of matrix in the ground-mass, where it obtains in the form of small laths and plates, sometimes with bifid or ragged terminations; and these microlitic felspars sometimes show a tendency to flow structure around the phenocrysts of felspar, augite and olivine. The rest of the ground-mass is made up of allotriomorphic grains and minute prisms of pale pink augite, and abundant grains and octahedra of black opaque magnetite.

Fig. 4. Olivine-Basalt, Thuringia, × 20.—*Left-hand semicircle.* Here the olivine, in much fissured yet singularly fresh crystals, plays the principal *rôle* as the prophyritic element. It obtains in form of very large colourless phenocrysts, a portion of one of which is shown intersected by the circumference; and small irregular colourless crystals which also show the roughened or shagreened surface-structure disseminated throughout the field. The idiomorphic eight-sided crystals are augite; the colourless small laths represent plagioclase felspar; the black specks, magnetite; and,

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lastly, a brown devitrified magma in which minuter crystals occur, but require a higher power for their resolution.

Olivine-Basalt, Squire's Hill, Antrim, × 20.—*Right-hand semicircle.* In this figure an appreciably vitreous base is diversified by closely packed microlitic plates and laths of plagioclase felspar and allotriomorphic grains and small stout prisms of a pinkish augite, with groups of black octahedra and granules of magnetite at irregular intervals. A larger crop of clear, colourless laths of plagioclase, and reddish to pale-yellow often idiomorphic crystals of olivine play the parts of phenocrysts.

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PLATE VI.

Fig. 1. Elvan, Chacewater, Cornwall, × 20.—The group of rocks, which are classed together under the Cornish miner's name *elvan*, comprise small bosses, dykes and veins of material having the same general composition as granite, and commonly occur as apophyses from some mass of granite sent through the surrounding structures. As a result of the conditions under which they became solid, the typical elvans, as demonstrated by the example here illustrated, consist of a micro- to a cryptocrystalline ground-mass, which, in the present instance, shows numerous lath-shaped crystules of triclinic felspar bound together by felsitic material composed of orthoclase and quartz. The phenocrysts in the picture show large turbid crystals of oligoclase, and a couple of clear colourless crystals of quartz, one of which shows the outlines of a section of the hexagonal pyramid and the other being somewhat rounded by corrosion. When highly magnified these crystals show many strings of glass inclusions, fluid pores, and negative crystals, which sometimes imprison a cube of rock-salt and an air bubble.

The *right-hand semicircle* shows another portion of the same slide, magnified 20 diameters, and viewed with polarised light. The ground-mass shows the microlitic felspars illuminated, and points of light in

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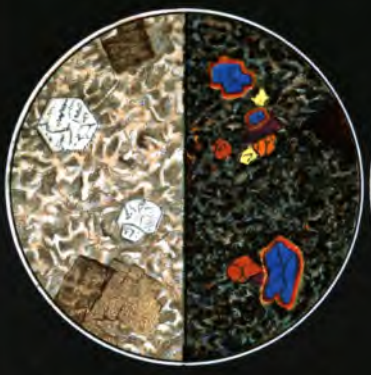

Fig. 1. ELVAN.
Chacewater, Cornwall, × 20.

Fig. 2. GRANITE.
Heidelberg, × 20.

Fig. 3. GRANITE.
Heidelberg, × 20.

Fig. 4. PEGMATITE.
Thuringia, × 20.

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vivid hues coming from the silica, so as to give it a characteristically dappled appearance. The circumference cuts part of a large altered crystal of triclinic felspar in a position of extinction, while the quartz phenocrysts are brilliantly illuminated with vivid blues, bordered with orange and other equally intense colours, thereby showing that the section must have been a very thick one; for when ground thin, to about ·001 inch, the interference tints given by quartz are decidedly weak, and range from blue-grey to white of the first order on Newton's scale of colours.

Fig. 2. Granite, Heidelberg, × 20.—This figure represents a thoroughly typical example of a two-mica granite. The stippled part of the picture indicates the portions of the felspars, of which there are two kinds,—orthoclase or potash-felspar at the top and middle-left, and plagioclase or triclinic felspar at the bottom towards the left. The micas are shown by a centrally situated lath of freely cleaved colourless muscovite or potash-mica, which is moulded at its upper edge upon a similarly shaped, but brownish-green flake of biotite or ferro-magnesian mica. Other crystals of muscovite are moulded upon the upper end of this lath of biotite, and it may here be noted, that this demonstrates the normal order of crystallisation of micas in granite, viz., that the muscovite took shape in advance of biotite. The quartz, which has been the last to crystallise in this rock, does not show idiomorphic contours, but fills up interspaces in the form of water-clear crystals pervaded by numerous strings and patches of inclusions.

Fig. 3. Granite, Heidelberg, × 20.—This shows the

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same portion of the slide described above, viewed with parallel polarised light. It will be observed that the orthoclase gives more or less flat interference tints, and that the polarised light reveals the presence of two brownish-yellow Carlsbad twins, also that the plagioclase felspar is unerringly located by its numerous parallel bands due to polysynthetic twinning on the albite type. The quartz in vivid blues, reds, purples, etc., bordered with crimson and yellow, denotes that the slice must have been a very thick one. The biotite is in a position of extinction, while the muscovite shows brilliant chromatic polarisation.

Fig. 4. Pegmatite (*Graphic Granite*) Thuringia, × 20. —The *left-hand semicircle* shows the appearance of the section when viewed by ordinary transmitted light, while the *right-hand half* of the picture represents its aspect under reflected light. The term pegmatite was applied by Haüy to indicate certain segregation veins which are found traversing abyssal rock-masses of normal structure, which show a strong tendency to graphic intergrowths, and are regarded as the pneumatolytic phase of solidification of the molten magma from which they were derived. They are typically composed of microcline or orthoclase felspar and quartz, and frequently display some white mica (muscovite) and sporadic crystals of garnet or tourmaline. Many of the foreign—notably American—pegmatites are rich in rare and special minerals. The example here figured shows the orientation of the quartz and felspar in a singularly well-developed pattern, called "graphic" by reason of its supposed resemblance to Hebrew writing. The quartz and the orthoclase have become intergrown

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with their principal axes parallel. By transmitted light the clear colourless quartz is seen to be pervaded by strings of inclusions, which are very clearly relieved as white meshes on a dark ground when viewed by reflected light. The intervening orthoclase shows its granular ultra-microscopic structure.

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PLATE VII.

Fig. 1. Luxulyanite, Luxulyan, Cornwall, × 20.—Tourmaline-granites, of which luxulyanite is a curious variety, appear to be special modifications of the normal granites in their neighbourhood. The picture shows the remains of a granulated crystal of light flesh-coloured orthoclase at the lower right-hand side, the remainder of the field being taken up by clear quartz (derived from the alteration of the felspar), which is crowded with stellate groups of tourmaline needles, cut in various directions, and exhibiting greyish-brown and indigo tints. These diminutive radially disposed needles attain the length of ·03 inch. In other parts of the slide are seen yellowish-brown plates and grains of tourmaline, which are assumed to represent the mica of the original granite.

Fig. 2. Hornblende-Syenite, Dresden, × 20.—This is accounted to stand as the typical syenite of modern lithologists, from *Plauenscher Grund*, in the neighbourhood of Dresden. The figure shows several dark-green crystals of hornblende of the pleochroic variety, the central one of which exhibits idiomorphic outlines, deficient, however, at the lower left-hand side of the section, which would otherwise show two clino-pinacoidal and four prismatic planes. Its cleavage lines, like those of the other sections in the picture which happen to have been cut perpendicular to the vertical axis, give an angle of 124°, which is distinctive of the mineral hornblende. The remainder of the field is filled

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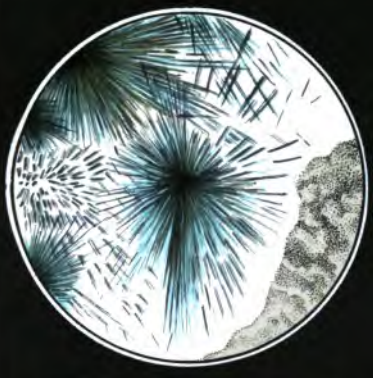

Fig. 1. LUXULYANITE.
Luxulyan, Cornwall, × 20.

Fig. 2. HORNBLENDE-SYENITE.
Dresden, × 20.

Fig. 3. TONALITE.
Adamello Alps, × 20.

Fig. 4. DIORITE.
Halsbrucke, × 15.

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by orthoclase felspar, which constitutes the bulk of the rock, but there is also some subordinate oligoclase, indications of which appear as two parallel lines just on the right-hand side of the upper apex of the lozenge-shaped, strongly contoured (and, therefore, highly refringent) crystal of yellowish-brown sphene, a second, somewhat tabular crystal of which lies attached to its lower boundaries. Sundry elongated minute colourless prisms and diminutive hexagonal sections of apatite may also be seen inclosed by both the hornblende and the orthoclase, and a small quantity of interstitial water-clear quartz in an aggregate of grains may be seen depicted midway below the central and lowermost crystals of hornblende.

Fig. 3. Tonalite, Adamello Alps, Tirol, × 20.—This picture shows the intimate structure of the well-known quartz-diorite of the Adamello Alps at Tonale, on the borders of Italy and the Tirol, and therefore called *tonalite* by Vom Rath. The *right-hand side* shows the section as it appears under crossed nicols. Its constituent minerals are: well-developed clear crystals of striated plagioclase showing a strong tendency to crystallographic contours. Under polarised light their multiple-twinning is strikingly apparent, and it can then also be made out that some clear orthoclase felspar forms irregular patches moulded on or inclosing the plagioclase. Of ferro-magnesian minerals, two brown laminated crystals of biotite are shown in the *left-hand semicircle*, one at the top and the other at the bottom, and both are cut by the circumference, while a greenish-brown irregular patch of hornblende, showing cleavage-traces which give the angle 124° 30′, is centrally situated.

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The mutual relations of these two last-named minerals vary, but both of them may be moulded on the plagioclase. In the part under polarised light both mica and hornblende give brilliant chromatic dark greens and reds, but the mica at the top is seen to be striated while the hornblende in continuation of the central patch on the left appears characteristically checkered. The colourless quartz is interstitial and abundant, and is clearly shown under polarised light in a mosaic of brilliantly coloured grains filling up the spaces between the minerals. In the *left-hand semicircle* two strongly contoured small but well-built prisms of zircon are shown inclosed in the plagioclase crystals at the upper and lower parts of the picture respectively.

Fig. 4. Diorite, Halsbrucke, Freiberg, × 15.—The brownish-green crystals in this illustration are of common hornblende, and are developed in such abundance as to almost justify the rock being called an amphibolite. The prismatic cleavage in these crystals is, as usual, well pronounced, and there also appears to be a second generation of small green prisms of the same mineral. The remainder of the rock is composed of somewhat brownish well-striated plagioclase felspar, with a very subordinate amount of clear grains of quartz, two very small patches of which are shown in the lower half of the figure. The black squares and specks, which are principally inclosed by the hornblende, represent octahedra and grains of magnetite, while some of the colourless contours within the large irregular hornblendes indicate apatite.

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Fig. 1. OLIVINE-DIABASE.
Whitwick Colliery, × 20.

Fig. 2. DOLERITE.
Dalmahoy Hill, × 15.

Fig. 3. DOLERITE.
Inchkeith, × 15.

Fig. 4. GABBRO.
Schlesien, × 20.

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PLATE VIII.

Fig. 1. Olivine-Diabase, Whitwick Colliery, Leicestershire, × 20.—This rock has often been described under the name dolerite, and, therefore, according to modern nomenclature, ought to be of volcanic origin; but the figure here shown is thoroughly characteristic of deep seated formation, and is possessed of all the distinctive features of a typical diabase which has not undergone any alteration. The portion of the slice depicted shows part of a very large plate of pale brownish-pink augite, intersected throughout by numerous laths of colourless plagioclase felspar (labradorite) which give rise to the *ophitic* type of structure in this holocrystalline rock. Towards the lower right of the picture there are sections of four patches of clear, colourless, much fissured olivine, all of which show roughened surfaces, while the two nearest to the right-hand side show traces of green serpentinous metamorphism along their fissures and boundaries. These olivines are more or less idiomorphic, and the uppermost patch is penetrated by a lath of felspar. Much confusion has arisen by the frequent employment of the term diabase to designate dolerites which have been altered by chloritisation.

Fig. 2. Dolerite, Dalmahoy Hill, Edinburgh, × 15. —The *right-hand half* under crossed nicols. This typical dolerite shows a plexus of lath-shaped plagioclastic felspar crystals (labradorite, colourless by or-

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dinary light but exhibiting polysynthetic twinning on the albite type with polarised light). The pinkish-grey augite is developed in allotriomorphic grains embedded between the felspars, but the adjacent grains show different orientations, and constitute the *granulitic* structure in these volcanic rocks. The greenish patches are principally chloritised alteration products (viridite), but sometimes a greenish sub-idiomorphic crystal of olivine may be detected. The black crystals are mainly magnetite; but ilmenite, sometimes showing leucoxenic change, is also present. In the half of the figure under polarised light the lamellated felspars are strikingly *en evidence*, but, by reason of the thickness of the slice and the low power used, the augite grains appear extinguished, while two rounded spots of vivid red reveal the presence of olivine.

Fig. 3. Dolerite, Island of Inchkeith, Firth of Forth, × 15.—This affords a good example of an altered dolerite, so-called "diabase" of some authors, which occurs as a volcanic intrusion through the contemporaneous carboniferous rocks. The felspar obtains in long laths of labradorite, manifestly of two generations, both of which intersect their neighbours irregularly. The interspaces are filled with allotrimorphic augite granules, while frequent large patches are filled with green decomposition products, manifested at the centre and at the top by irregular rounded masses of secondary calcite, amidst which the peculiar vermicular variety of chlorite called *helminth* is strongly developed in bands and twisted rings, which, under a high power, show a fibrous radial structure.

Fig. 4. Gabbro, Schlesien, × 20.—The *right-hand*

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half of this illustration is shown under parallel polarised light. The drawing demonstrates the typical coarsely holocrystalline character of the rock, the individual minerals of which are developed in allotriomorphic forms. The felspar, which is colourless and much fractured, gives the large extinction angles under crossed nicols diagnostic of anorthite, and bears evidences of change at places into a more or less whitish opaque substance called *saussurite*. This saussuritisation is shown in form of an irregular band of grey traversing the field sub-horizontally in the *left-hand half* of the picture immediately below its equator, and on the right-hand polarised field a tapering irregular band passes upwards at the bottom of the field, traversing through an obliquely brown-banded crystal of plagioclase. When carefully resolved under higher powers and varying optical conditions the saussurite is found to be composed of a heterogenous yet intimate aggregate of fibres and granules of secondary water-clear albite crystules, prisms of zoisite, shreds of actinolite, grains of epidote, and a little calcite and chlorite. The finely striated irregular crystals which constitute the remainder of this rock are diallage,—a laminated variety of augite.

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PLATE IX.

Fig. 1. Gabbro, Radanthal, Harz, × 15.—Exhibits the typical intimate structure of the group to which it belongs, and shows the *right-hand half* of the field of view under crossed nicols, while the other half remains under ordinary transmitted light. The texture is coarsely holocrystalline, and composed of allotriomorphic forms, with colourless plagioclases (anorthite) as the dominant constituent, which under polarised light shows a tendency to develop idiomorphic contours, and are seen to be repeatedly twinned on the albite type, the parallel lamellæ appearing for the most part in alternately lighter and darker shades of neutral tints, Next in abundance comes the augite, in pale pinkish-brown irregular crystal-plates and wedges. Across the centre, and at the lower margin in the *left semicircle*, the augite shows the usual prismatic cleavage, 87°, and an orthopinacoidal cleavage and *diallagic structure* are shown in the crystal at the upper part of the picture. It is worth while remembering in this connection that the fine lineation parallel to the orthopinacoid is diagnostic of diallage, and when the faces of this pseudo-cleavage, which exhibit a pearly lustre, are flaked off and examined in convergent polarised light, they present the oblique emergence of an optic axis, which serves to distinguish diallage from the rhombic pyroxenes. The small dark yellowish-brown irregular compound flakes shown by ordinary light are accessory crystals

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Fig. 1. GABBRO.
Radanthal, Harz, × 15.

Fig. 2. PAULITE-NORITE.
Banff, Scotland, × 15.

Fig. 3. PAULITE-NORITE.
Banff, Scotland, × 15.

Fig. 4. PICRITIC-SERPENTINE.
Menheniot, Cornwall, × 25.

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of biotite, and the black patches of iron ore which are here more frequently developed than usual, are combinations of both ilmenite and magnetite,—titanomagnetite. In the polarised part, the diallagic augite and the biotite both show brilliant interference tints.

Fig. 2. Paulite-Norite, Banff, Scotland, × 15.—This surpassingly beautiful rock was first unearthed by the late Professor Heddle of the University of St. Andrews some two-and-twenty years ago at Banff, when he sent the writer some of the first specimens under the name of "Paulite-Diorite." The rock, however, is a true norite, as will be seen from this figure which shows large irregularly shaped plates of colourless but oftentimes murky felspar, with an almost equal proportion of allotriomorphic purplish-brown rhombic pyroxene of the variety called *paulite*, which shows "*schiller structure*,"—not inaptly termed by Heddle "*herring-shoal structure*,"—to perfection. Towards the upper left-hand boundary there is part of a crystal of olivine, exhibiting serpentinised fissures and the characteristic "shagreened" superficial markings on the fresh kernels of the mineral. Subjoined thereto is part of a greenish-grey crystal of hornblende showing prismatic cleavages, the cleavage lines intersecting at an angle of 124°.

Fig. 3. Paulite-Norite, Banff, Scotland, × 15, under crossed nicols. The felspar crystals are here seen to be broadly banded on the albite type, denoting their plagioclastic character, while their large extinction angles serve to show that they belong to the anorthite end of the lime-soda series. The crystal of felspar coloured brown, at the upper left-hand boundary, also shows pericline striation, while the deeply neutral-tinted

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crystal immediately below shows that it is formed of wedged-shaped lamellæ. The centrally situated patch of green diversified at places by complementary red, especially at the right-hand side, is a large plate of paulite showing Heddle's "herring-shoal structure" with great clearness. At the extreme right equatorial boundary there is a very small portion of an olivine crystal, with fissures of black separated magnetite granules.

Fig. 4. Picritic-Serpentine, Clicker Tor, Menheniot, Cornwall, × 25.—This remarkable rock exhibits with the utmost clearness the conversion of a picrite of the Inchcolm type into a beautiful dark green serpentine, mottled with whitish grey and speckled with black. The figure shows that the green serpentine has resulted from the combined alteration of its three principal constituents,—olivine, augite and felspar. It depicts part of a large plate of light pink augite inclosing a yellowish-green crystal of altered olivine in pœcilitic fashion, at the middle left-hand side, and the remains of dark brown ophitic laths of felspar towards the bottom of the picture. The remainder of the illustration shows the green serpentine in varying degrees of intensity, from yellowish to bluish fairly dark green and very faint almost colourless hues. At the top and along the whole of the right-hand side, and also at the bottom left-hand boundary, the serpentine shows unmistakable signs of having been derived from olivine by the distinct traces of *mesh structure* bounded by more or less crystallographic contours, while the large plate of augite immediately to the right of the ophitic felspar below, and on the left median upper boundary is manifestly

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undergoing disintegration into a kind of *netted structure*, and insensibly merging into the surrounding serpentine. The brown decaying vestiges of felspar, which is least in abundance among the original constituents of this rock, are also seen to be passing into and mingling with the green serpentine at the left-hand side. This alteration product from the felspar is probably what has often been called *pseudophite*, a substance which retains the original alumina of the felspar in combination with magnesia and water after the lime and alkalies have been removed. The felspar, when fresh, was probably a form of anorthite. The black specks showing square, lozenge-shaped, and rounded outlines represent sections of magnetite, and give the glancing blue tint when viewed by reflected light.

Other parts of the section, not shown in this figure, reveal sundry patches of ruddy-brown bordering the augite crystals at places; these may be in some cases the form of spinel known as picotite, and in others may be marginal intergrowths of basaltic hornblende. Laminated brown flakes of biotite likewise occur here and there, and in their neighbourhood may also be seen a few strongly refracting colourless hexagons and elongated transversely jointed sections of minute apatite prisms. Occasionally a little titaniferous iron is present in the form of elongated, corroded, and also skeleton, black, opaque crystals.

With higher powers, ranging from 100 to 500 diameters, some parts of the augite crystals are seen to possess a lineated greenish diallagic structure, and when the black lines and patches in many of the olivine pseudomorphs are closely scrutinised they will be seen

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to consist of secondary granules of magnetite, accompanied by faint green and colourless needles developed in three directions at right angles to each other. These microlites are referred to *grammatite-like* amphibole, which doubtless arise in connection with the conversion of the olivine into serpentine.

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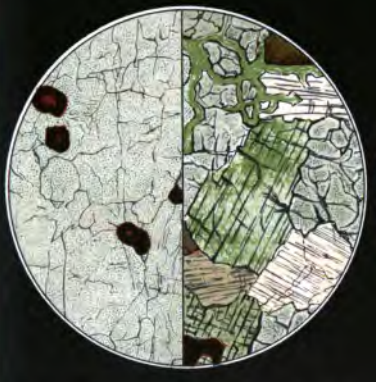

Fig. 1. DUNITE.
Mt. Dun, New Zealand, × 15.
LHERZOLITE. Etang de Lherz, × 15.

Fig. 2. OLIVINE-SERPENTINE.
Saxony, × 20.

Fig. 3. ENSTATITE-SERPENTINE.
Baste, Harz, × 20.

Fig. 4. NEPHELINITE.
Odenwald, Germany, × 15.

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PLATE X.

Fig. 1. *Left-hand semicircle.* **Dunite,** Mount Dun, New Zealand, × 15.—The entire field is here shown to consist of compacted crystals of fresh colourless olivine exhibiting "shagreened" surfaces and fissures of black lines, which, with a higher power, show separated grains of magnetite. Another spinellid also occurs in the form of grains of coffee-brown picotite; while red garnet (pyrope), not shown in the figure, has also been frequently detected in the rock.

Right-hand semicircle. **Lherzolite,** Etang de Lherz, Pyrenees, × 15. — This well-known rock may be described briefly as an enstatite-augite-peridotite. The dominant constituent olivine is shown at the equatorial boundary in colourless "shagreened" grains with irregular black fissures, occasioned by the highly refringent nature of the mineral coupled with separations of granules of magnetite. At the top apex there is more olivine, which stretches downward along the polar diameter to tail off at the equator. This patch of olivine is seen to be freely traversed by sinuous paths of green serpentine. At the upper right-hand boundary is an intersected patch of deep-brown chromite, limited below by a veinlet of green serpentine, which also penetrates the subjacent crystal of faint-brown enstatite. Lower down, immediately under the olivine already noted, there is another crystal of light-brown rhombic pyroxene (enstatite) characterised by the possession of

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a fairly perfect pinacoidal cleavage. The light-green central and inferior crystals are monoclinic pyroxenes (augite) of the nature of chrome-bearing diopside. The lower crystal shows cleavages parallel to the prism, of 87°.

Fig. 2. Olivine-Serpentine, Saxony, × 20.—The *left-hand half* under ordinary, and the *right-hand semicircle* under parallel, polarised light. This serpentine appears to be of picritic origin, and closely approaches the type of rock from Clicker Tor, Menheniot, Cornwall. In the portion viewed with ordinary light, the bulk of the rock is seen to consist of olivine crystals closely compacted together, some of which exhibit hexagonal outlines. In most cases the crystals show kernels of fresh olivine, which, in the part under crossed nicols, are seen to give brilliant interference tints; while their margins and fissures of metamorphism, which have undergone the change into serpentine, are shown under polarised light in steel-blue and neutral hues. The *left-hand semicircle*, moreover, shows black lines along the fissures of the olivine, which are occasioned by the separation of granules of magnetite; while sundry black specks and patches show the presence of probably original magnetite and ilmenite, and grey to green interstitial matter represents decomposition products (viridite, chlorite, and amorphous calcite). The pinkish crystals are the remains of tolerably fresh diallagic augite; while traces also occur, in ophitic fashion, of much decomposed plagioclastic felspar, which doubtless formed a subordinate part of the original rock-mass.

Fig. 3. Enstatite-Serpentine, Baste, Harz Mts.,

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× 20. — *Left-hand semicircle* under ordinary, and the remainder under crossed nicols. In contra-distinction to the *mesh-structure* characteristic of serpentine derived from olivine, as shown in the preceding example, the serpentine here depicted is derived from enstatite (rhombic-pyroxene), and exhibits an equally peculiar form known as *bastite-structure.* The entire field is composed of a huge pseudomorph of bastite after enstatite, with portions of crystals of olivine cut by the circumference at the top and on either side. These olivines may be known by their fissures of metamorphism forming a mesh-work, which incloses fresh kernels of the mineral; the latter exhibiting roughened or "shagreened" surfaces. The olivines in the part of the field viewed with ordinary light are colourless, with pale-green serpentinised fissures; while those under crossed nicols show brilliant reds and blues, with fissures of the pale steel-blue or neutral tints characteristic of serpentine. It will be noticed that fissures filled with serpentine are seen to radiate from the olivines and to anastomose freely in the substance of the large plate of bastite which incloses the olivines in pœcilitic fashion in this rock. These radiating fissures are attributed to the expansion of the olivine during its alteration, whereby cracks are forced open in the surrounding textures and subsequently filled with infiltrated serpentine. At the base of the polar diameter there is a segmental patch of bastite which has undergone complete metamorphism into serpentine. This is evidenced, in the part under polarised light, by the absence of the vivid interference colours which distinguish the remainder of the plate of

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bastite above. Upon careful scrutiny it will be seen that the bastite pseudomorph under ordinary light is of a pale greenish-grey colour and is very finely striated. These *striæ* are composed of more or less parallel fibrils which are traversed by the serpentinous fissures from the olivines, already alluded to, but do not cross the cracks, thereby showing that the bastite modification of the original enstatite must have been completed before the fissures from the olivines were forced open and filled with serpentine. The fibrils themselves give straight extinction; but, by reason of deviating from a strictly parallel arrangement, offer the characteristic appearances shown in the picture, especially by the portions under polarised light.

Fig. 4. Nephelinite, Odenwald, Germany, × 15.—This picture portrays the general characteristics of a fairly good nephelinite passing into a nepheline-basalt by reason of its containing a subordinate quantity of olivine. An idiomorph (six-sided) of red-brown olivine is shown in the polar diametric line not quite half-way above the radius from the centre. The bulk of the rock is composed of cloudy-white nepheline and green augite, with brown biotite, and a few black compound crystals of titaniferous magnetite. A little apatite also occurs, but is not shown in the drawing except by a small hexagonal colourless cross-section towards the edge of the lower right-hand quadrant of the circle; but higher powers reveal that mineral in tolerable abundance throughout the field. The biotite, it may be noticed, shows resorption phenomena. By reason of its feeble double refraction nepheline polarises in greyish, yellowish, brownish, and neutral tints under crossed nicols;

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and when its occurrence is doubtful or difficult to localise, micro-chemical confirmatory tests may be applied. To carry these out successfully, thin sections of the rock should be subjected to the reaction of hydrochloric acid until the nepheline has been gelatinised; these parts can then be stained with fuchsine-red or nigrosine-black, and thus readily identified under the microscope.

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PLATE XI.

Fig. 1. Leucitite, Capo di Bove, Alban Hills, near Rome, Italy, × 20.—*Left-hand semicircle* under ordinary and *right-hand semicircle* under polarised light. When the felspathoid mineral leucite occurs in a basic lava to the exclusion of felspar and is free from olivine, the rock in modern lithology is termed a leucitite, and the example here chosen is thoroughly typical. The field of view shown by the picture, exhibits numerous octagonal colourless crystals of leucite, which are sections through small idiomorphs formed of a combination of a di-tetragonal with a tetragonal pyramid. These small colourless crystals usually contain inclusions of dark isotropic glass, magnetite, felspar, or pyroxene generally disposed in a circle of dots, lying approximately parallel to the boundaries of the crystal, but sometimes centrally aggregated, or irregularly disseminated. These are accompanied by a few pale green augite crystals and black specks of magnetite, and the whole of these constituents are inclosed in pœcilitic fashion by a large plate of striated yellowish-brown melilite. Under polarised light many of the small leucites become extinguished, but some of them show numerous twin lamellæ of both broad and narrow bands, differing in intensity of neutral tints; the twinning planes of these polysynthetic systems being developed in four directions, and giving to the crystals their peculiar geometric patterns. The striæ of the plates of melilite, moreover,

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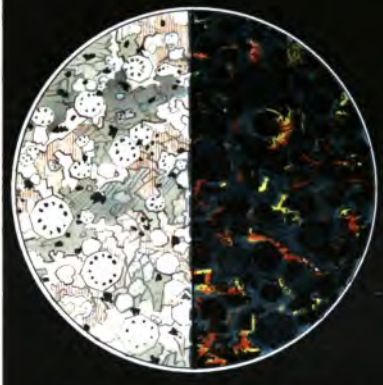

Fig. 1. LEUCITITE.
Capo di Bove, Rome, × 20.

Fig. 2. PHONOLITE.
Wolf Rock, Cornwall, × 20.

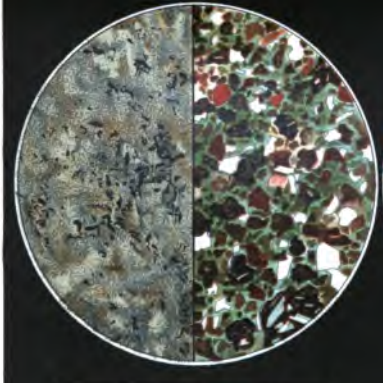

Fig. 3. VOLCANIC TUFF.
Braid Hills, Edinburgh, × 20.
PALAGONITE TUFF.
Burntisland, Fifeshire, × 20.

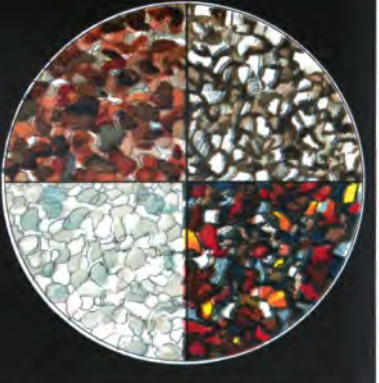

Fig. 4. ARENACEOUS ROCKS, × 15.
FERRUGINOUS SANDSTONE.
GREYWACKE.

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when carefully scrutinised under high powers, exhibit the peculiar fusiform outlines known as "peg-structure," but this is, for obvious reasons, not shown by the drawing.

Fig. 2. **Phonolite**, The Wolf Rock, off Land's End, Cornwall, England, × 20.—*Right semicircle*, viewed by ordinary transmitted light. The upper half of this figure shows four elongated, columnar, colourless, and much transversely fissured crystals of sanidine felspar; parts of two crystals, at the apical angle, exhibiting a tabular habit, and several small transverse hexagonal and rectangular colourless crystals of the same mineral in a hemi-crystalline ground-mass, composed of small lath-shaped prisms of the green soda-pyroxene, called ægirine, irregularly scattered among minuter lath-shaped crystals of colourless sanidine; still smaller hexagonal and rectangular water-clear crystals of nepheline, minute cloudy crystals of nosean and haüyne, and a very minute quantity of iron ore. There is also a small phenocryst of nosean with a dark-bordered core and lighter outer zone, situated near the diametric line. In the lower half of this semicircle, a precisely similar ground-mass contains a large irregular compound phenocryst of nosean, with its light outer zone and dark core. *Left semicircle*, under polarised light. The crystals of sanidine appear in neutral tint. A large square section towards the centre of the figure, shows the transverse aspect of a phenocryst of columnar, zoned sanidine, with an inclusion of well-illuminated ægirine crystals. At the upper apex, is a tabular crystal of sanidine showing the plane of composition of the binary Carlsbad twin. A little lower down and partially cut

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off by the circular boundary is another twinned phenocryst of sanidine in cross-section. Lath-shaped sanidines some of which show traces of twinning, are disseminated throughout the field. The black opaque sections show the positions of the noseans and haüynes. The glimmerings of green and yellow indicate the ægirines; while the very minute illuminated dots represent the smaller sanidines and nephelines.

This phonolite or "clinkstone" as it is popularly called, is unique among British stones, as the only nepheline-bearing lava *of its kind* in the United Kingdom. The nepheline is extremely difficult to locate with precision in the rock-mass, by reason of its minute size, its pellucidity and the shape of its sections, which are apt to be confused with those of the sanidine. Its determination, however, may be readily effected by the simple micro-chemical means of etching the slice of rock with hydrochloric acid to gelatinise the nepheline, and then staining these spots with a solution of fuchsin-red or nigrosin-black.

Fig. 3. *Left-hand semicircle.* **Volcanic Tuff,** Braid Hills, Edinburgh, × 20.—This is a good typical example of an excessively fine-grained pyroclastic rock, formed by the deposition of highly comminuted dust or ash, mainly of a felsitic nature. Even with a high power of the microscope, the minute particles appear to be granular and of fairly uniform sizes; but slight differences become apparent by the segregation of particles containing more or less iron oxide, into nascent stellate groups (incipient crystals), which give to the reddish purple rock a mottled appearance in hand specimens. The original Braid Farm Quarry, on the

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outskirts of Edinburgh, from which this specimen was obtained now forms the site of a small hotel; but abundant specimens of the rock may still be found forming the roadside walls (dykes) along the road leading to the Braid Hills from Morningside.

Right-hand semicircle. **Palagonite Tuff,** Burntisland, Fifeshire, × 15. — The example here depicted is a tolerably coarse fragmental volcanic rock, which has undergone profound changes since its deposition. It forms one of a series of submarine tuffs, which Sir Archibald Geikie located as occurring abundantly among the carboniferous formations in the basin of the Firth of Forth. The bedded tuff consists of a comparatively fine textured matrix, inclosing fragments of lava which Geikie avers are the *débris* of previously consolidated rocks rather than true lapilli; for they are usually very vesicular throughout and the vesicles are frequently cut by the external surface of the fragment. Such a fragment presumably of a basalt is shown at the lower boundary of the figure, as well as in smaller patches throughout the field. The matrix is composed of clear colourless blebs of quartz; although some of these clear parts consist of plagioclastic felspar. This can, of course, be readily determined by the revelation of lamellæ when viewed with polarised light. The brown fragments correspond to the *palagonite* of Waltershausen, and clearly result from the decomposition of vitreous particles. The greenish interstitial matter, is also a product of alteration, and is referable to chlorite.

Fig. 4. Arenaceous Rocks, × 15. — *Upper left-hand quadrant.* **Ferruginous Sandstone,** as viewed with

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ordinary transmitted light. The *allothigenous* constituents of this rock, show it to be made up of tolerably uniform-sized particles of sand, most of which are fairly well-rounded by attrition. These grains are very compactly cemented together by secondary or *authigenous* constituents, composed of a pellicle around each grain of more or less yellow, red, brown, and greenish silicates of iron coupled with secondary silica derived from the grains themselves. That such is the case, is clearly demonstrated by the simple micro-chemical test of subjecting a slice of the rock to the reaction of hydrochloric acid, which has the effect of dissolving away the iron colouring matters surrounding the grains and leaving them clear, as shown by the *lower left-hand quadrant.* The section so treated, may then be examined under polarised light to show that the grains are held together by interstitial silica derived from the grains themselves, this being revealed by the fact that contiguous portions extinguish simultaneously with the grains from which they have emanated.

Upper right-hand quadrant. **Greywacke.**—This is a very old and formerly loosely applied term which has recently been revived to signify those rocks of complex constitution, which, although they are closely allied to the arenaceous group, cannot yet be accurately classified as sandstones or grits. From the figure, which is a typical greywacke in its modern sense, it will be seen that the texture consists of more or less angular but sometimes rounded fragments of clear, colourless, and dirty-looking particles, bound together by a much darker cement. The *lower right-hand quadrant* shows another portion of the same slide under crossed

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nicols. This reveals that the majority of the fragments are quartz, and that the cement is siliceous; but there are also a few fragments of felspar which show unmistakable signs of lamellation on the albite type. Other minerals and fragments of rocks may, of course, enter into the composition of greywacke, and the cementing substance need not invariably be silicious although it usually is so.

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PLATE XII.

Fig. 1. *Left-hand semicircle.* **Oolitic Limestone,** Ireland, × 15.—This illustration exhibits a singularly well-developed typical oolite viewed under ordinary light. The bulk of the rock-mass is seen to consist of numerous spheroidal grains formed of successive layers of calcareous material imbedded in a mosaic matrix of clear colourless calcite, which gives to the whole a strong resemblance to fish-roe—hence the name oolite or roestone. It will be observed that in addition to the concentric coats a more or less evident radial structure is also developed; and, upon closer scrutiny, it will be found that the minute particles which go to build up the layers are themselves disposed either radially or tangentially. Hence, if the grains happen to be approximately spherical and free from molecular changes, such sections ought to give a black cross under polarised light. The layers are usually deposited upon a nucleus, such as the test of a foraminifer, the fragment of a shell, a quartz grain or particle of calcareous mud; and, naturally, the ultimate shape of the oolite depends upon the original form of the nucleus. The oolites thus formed in shallow waters are cemented together by calcareous material, and subsequent events tend to cause the cement to become calcified into the tessellated matrix of crystalline calcite so clearly shown in the picture.

Right-hand semicircle. **Freshwater Limestone,** Swan-

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Fig. 1. Oolitic Limestone. Ireland, × 15.
Freshwater Limestone. Swanage, × 15.

Fig. 2. Chalk.
Elaborated Picture, × 20.

Fig. 3. Nummulitic Limestone.
India, × 20.

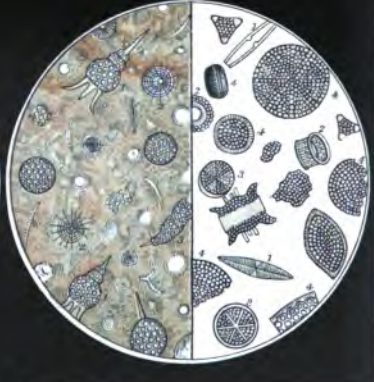

Fig. 4. Barbados Earth, Barbados, × 25.
Diatomaceæ, Peruvian Guano, × 250.

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age, × 15.—In this picture the shells of a variety of molluscs, chiefly lamellibranchs, are seen to be imbedded in a thoroughly calcified matrix composed of a mosaic of crystalline calcite. Many parts of these shells were probably composed of the unstable rhombic form of carbonate of lime known as aragonite; but this has manifestly been entirely replaced by the stabler calcite, which not only forms the matrix, but, by taking the place of the former aragonite of the shell substance, recrystallises into somewhat coarser tesseræ, and thereby drives all impurities to the edges of the shell which thus become emphasised by darker boundaries.

Fig. 2. Chalk, × 20.—This is an elaborated picture of what a perfect section of chalk ought to represent under a low power of the microscope, with the single exception of certain of the bodies marked *x*, to signify *coccoliths*, which require a comparatively higher power—from 200 to 1000 diameters—for their resolution. The figure shows a ground-mass of ultra-microscopic particles, presumably of amorphous carbonate of lime, being the comminuted products derived from the disintegration of the minute tests, mainly of foraminifera, which lie imbedded in the texture. In the present instance the matrix has not undergone calcification, or more properly speaking, recrystallisation; while the organisms are projected in hypothetically entire outlines in order to convey a correct conception of species.

Here the Huttonian dictum that "the present is the key to the past," is exceptionally well exemplified, especially by the light thrown upon contemporary deep-sea formations. Multitudes of pelagic organisms possessed of skeletons or hard parts live and die at the

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surface of oceanic and inland sea waters, and their remains subside to the bottom, undergoing both physical and chemical changes according to the depth, to accumulate and ultimately to consolidate into rock-masses. In typical chalk the majority of these minute tests consist of the calcareous skeletons of *Foraminifera*, mixed with the armatures of certain *Algæ* (coccospheres and rhabdospheres, etc.), and sundry siliceous skeletons of *Radiolaria, Diatomaceæ, Spongidæ*, and the like. By subsequent changes iron oxides segregate into frequent brownish and yellowish grains, and certain spaces—usually the chambers of organisms — become filled with green glauconite. The restored outlines of the most frequent organisms which occur in chalk are depicted and lettered in the figure as follows: *g. Globigerina, t. Textularia, n. Nodosaria, m. Miliola, m'. Section of Miliola, r. Rotalia, c. Cristellaria, l. Lagena, x. Coccoliths.*

Fig. 3. Nummulitic Limestone, India, × 20.—To record that all limestones are wholly derived from organic remains would be far from correct, but that many of them are so constituted is well attested to by the present example, which shows a rock-texture composed of a matrix of ultra-microscopic particles of ferriferous carbonate of lime in which are imbedded the fossil remains of numerous *Foraminifera* of the family *Nummulinidæ*, characterised by the curious formation of their complicated septated chambers, which are shown with almost diagrammatic distinctness in the drawing, which portrays peripheral as well as horizontal and tangential sections through the tests of the organisms *in situ* within the matrix. It will be observed that the internal chambers of the shells are more or less

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filled with the fine paste of the matrix, which has not undergone any recrystallisation; while evidence of the fact that the matrix is principally derived from the disintegration of the organisms is to be found in the numerous fragments of tests of all sizes, which are thickly disseminated throughout the matrix.

Fig. 4. *Left-hand semicircle.* **Barbados Earth,** Barbados, West Indies, × 25.—To understand the true significance of this remarkable deposit of siliceous rock, a glance at what is taking place in mid-ocean in the present day may not be amiss. It has been ascertained that extensive tracts of the ocean-floor in its deepest places are being enriched by the deposition of myriads of the siliceous tests, mainly of *Radiolaria,* which have more or less successfully resisted the solvent and disintegrative action of the sea water. These are found associated with a few skeletons of *Foraminifera* and sundry spicules of sponges, tunicates and other forms of life imbedded in an ultra-microscopic matrix of calcareo-siliceous matter derived from substances which have succumbed to the influences of the sea. Of this nature are the now familiar types of *Radiolarian-* and *Diatomaceous-oozes,* so called by reason of the predominance in them of the tests of radiolarians and the frustule-valves of diatoms respectively. Barbados earth, a general view of which is here afforded, is the fossilised equivalent of the radiolarian-ooze. The figure shows an ultra-microscopic matrix of a brownish-grey colour, in which are the plentifully-scattered fragments of radiolarians (*Polycystinæ*) and several exquisitely delicate entire tests of the genera *Podocyrtis, Stylodictya,* and *Eucyrtidium.* A few plain annular forms are also shown,

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which doubtless represent survivals of coccoliths and the primordial cells of *Globigerinidæ.*

Right-hand semicircle. **Diatomaceæ** from Peruvian Guano, × 250.—Although guano can scarcely be yet awhile called a rock, the vast deposits which occur in various parts of the world—notably in Peru—invariably furnish a fertile soil for the growth and development of diatoms. When isolated and cleansed the frustule-valves of silica present many marvellously-beautiful forms,—the following being diagrammatically figured in this picture: 1. *Navicula*; 2. *Galionella*; 3. *Actinocyclus*; 4. *Coscinodiscus.*

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Fig. 1. TORBANITE, × 20.
SPORIFEROUS COAL, × 20.

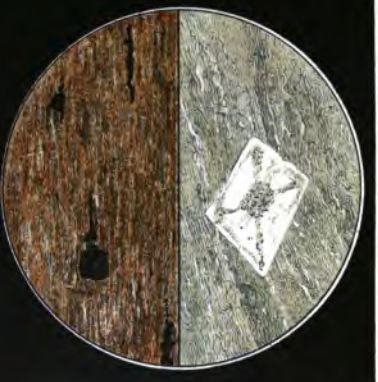

FIG. 2. CLAY SLATE, Bangor, × 20.
CHIASTOLITE SLATE, Skiddaw, × 20.

Fig. 3. STATUARY MARBLE.
Carrara, Italy, × 20.

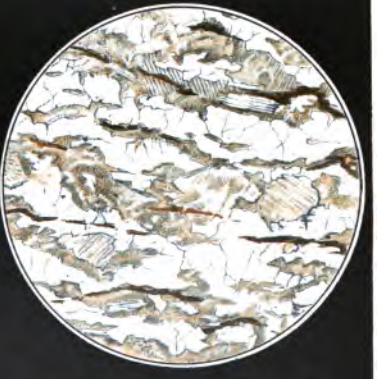

Fig. 4. GNEISS.
Freiberg, Germany, × 15.

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PLATE XIII.

Fig. 1. *Left-hand semicircle.* **Torbanite,** × 20.—In exemplification of the organic origin of coal, where structural details have not been totally masked by mineralisation, the substance called *torbanite* or *boghead coal*, affords ample testimony. In the picture the carbonaceous matter exhibits with great clearness the outlines of the original cells which formed part of the woody tissues probably from an oblique tangential section through the closed fibro-vascular bundle of a cryptogamic plant.

Right-hand semicircle, **Sporiferous Coal**, × 20.—This picture represents a section through a piece of brown coal, crowded with the spores of cryptogamic plants. The outlines of the spores are exceptionally well relieved by the formation of a marginal layer around each of amorphous white calcite, while the surrounding matrix of rich brown hue appears to have preserved the outlines of what were once well formed woody fibres in longitudinal section.

Fig. 2. *Left-hand semicircle.* **Clay Slate,** Bangor, N. Wales, × 20.—In former times clay slates were believed to consist essentially of detrital matter (allothigenous) while the term *phyllite* was applied to rocks which were clearly seen to be largely if not entirely reconstituted in place (authigenous). Such a distinction, however, has been shown to be but artificial, for no sharp line of demarcation can be drawn between clay slates and

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phyllites under the search-light of microscopical investigation. When a specimen of clay slate is examined under varying powers of the microscope, the majority of its particles are seen to be much too small to afford any certain clue as to their detrital origin, nor is it safe to say exactly whether or not the authigenous constituents were formed through the agency of dynamic metamorphism. The latter, however, most certainly accounts for the superinduced *slaty* cleavage, which is quite independent of the layers of deposition, and takes up a new direction along planes perpendicular to the maximum pressure by which the rock has become altered. In the figure it will be seen that the bulk of the rock consists of an excessively fine paste of brownish-grey particles arranged in parallel series, and inclosing lenticular colourless patches. Optical determinations with high powers, coupled with chemical analysis, prove that this paste consists of a secondary substance composed of a mixture of muscovite (potash-mica), and a chloritoid mineral, while occasionally when secondary changes have not advanced quite so far, pulverulent quartz, felspar and possibly kaolin of detrital origin may also be detected. High powers also reveal the presence of numerous needles of rutile, called *clay-slate needles*, and these are likewise of secondary origin, though not necessarily attributable to mechanical metamorphism. The large black crystals are sections of iron pyrites, which, when viewed by reflected light are characteristically of brassy appearance. Very often these crystals of pyrite are surrounded by lenticular patches of chlorite which sometimes adheres so tenaciously to the matrix that it becomes torn away

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from the core of iron sulphide, and the space thus left subsequently becomes filled up with infiltered quartz.

Right-hand semicircle. **Chiastolite Slate**, Skiddaw, Cumberland, × 20.—The matrix of slate in this figure affords a good example of *false cleavage*. This consists of a parallel system of microscopic faults, which has the effect of inducing a direction of weakness approaching to that of the true cleavage. In this matrix is seen imbedded a particularly fine crystal of chiastolite in cross-section, the chiasmal impurities which characterise this mineral being aggregated at the centre and stretching therefrom to the lateral edges of the rhombic prism, *i.e.*, to the angles of the section. The chiastolite occurs only at those parts of the Skiddaw slate which come into proximity with the granite, and is recognised to be an early effect of *thermal* metamorphism.

Fig. 3. Statuary Marble, Carrara, Tuscany, Italy, × 20.—The so-called *saccharoid* or *lump-sugar structure* of many marbles and limestones which may or may not be developed by both thermal and dynamic metamorphism, is typically exemplified by this figure which shows a section of the rock under ordinary light at the left and by polarised light at the right hand half of the picture. The texture is shown to consist of closely compacted allotriomorphic grains of crystalline calcite, in which lamellæ and intersecting cleavage planes can be distinctly discerned. Under crossed nicols the compound character of the individual granules becomes more plainly manifested by the difference in interference colours developed in their lamellæ which denote a system of twinning parallel to the face-$\frac{1}{2}$ R (Naumann's notation), and each grain is mapped out from its

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neighbours, to show that its planes of twinning are self-contained, and bear no relation whatever to those of contiguous grains.

Fig. 4. Gneiss, Freiberg, Germany, × 15. — There can be little doubt that the manifestly foliated character of this rock is due to dynamic metamorphism, — the original rock-mass having been a two-mica granite. The mineralogical characters of the rock are preserved in their integrity. There are two varieties of felspar, both of which appear light-brown in the section, the orthoclase however is cloudy, while the plagioclase exhibits faint lamellæ which would, of course, become strongly pronounced under polarised light. The bands of quartz are colourless, and abundantly traversed by "strings" of inclusions, and there are two kinds of mica. Of these the thin laths of dark-brown represent the ferro-magnesian biotite, which is strongly pleochroic, and the striated colourless laths, which also occupy the lines taken by the biotite, are potash-mica (muscovite). The muscovite is not pleochroic, but, under revolution between crossed nicols, gives vivid chromatic polarisation.

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Fig. 1. KINZIGITE.
Kinzigtal, Germany, × 15.

Fig. 2. GARNETIFEROUS MICA-SCHIST.
Memendorf, Saxony, × 15.

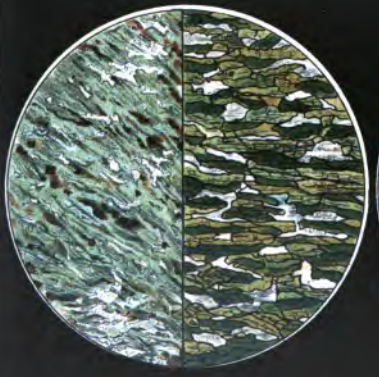

Fig. 3. CHLORITE-SCHIST.
Chemnitz, Saxony, × 15.
HORNBLENDE-SCHIST.
Bay of Nigg, Kincardine, × 20.

Fig. 4. GLAUCOPHANE-SCHIST.
Isle of Syra, × 20.
AMPHIBOLITE. Pyrenees, × 20.

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PLATE XIV.

Fig. 1. Kinzigite, Kinzigtal, Schwarzwald, Germany, × 15.—This noteworthy rock may be tersely defined as a garnet-biotite-plagioclase gneiss, and has undoubtedly been formed as a result of thermal metamorphism. The left-hand portion of the figure is shown under ordinary light, while the right-hand side is as it appears under crossed nicols. The centre of the field is occupied by a large hexagonal section of garnet, while a portion of another section of the same mineral is shown intersected by the circumference at the bottom of the picture immediately to the left of the dividing diameter. Under ordinary light these sections show bold contours, by reason of their high refractive indices; while the half of the centrally-situated crystal remains extinguished (even when revolved) in the polarised field. The colourless parts, on the left field of view, consist of quartz and plagioclase felspar in rude foliar arrangement. The felspar crystals are somewhat clouded with faint brown, but the quartz stands clear and colourless save for its "strings" and specks of inclusions. Under polarised light these two minerals are sharply defined from each other—the felspar exhibits numerous striæ due to albite twin-lamellæ, while the quartz gives quite flat tints (bright blues and yellows in the picture). The biotite is shown in pale brown striped scales and darker brown patches at the left-hand side; while the black specks indicate the positions of the magnetite, which is

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subordinate. In the polarised part the biotite exhibits bright colours in fine lamellæ, which however are totally distinct in appearance from the definite, fairly-parallel bands of twin-lamellæ shown by the crystals of plagioclase.

Fig. 2. Garnetiferous Mica-Schist, Memmendorf, Saxony, × 15. — In illustration of a rock having a distinctly crystalline texture which is further possessed of a parallel arrangement of its mineral constituents, no better example could be indicated than the one here chosen. The schistosity of the mass has clearly been superinduced by dynamic agency brought to bear upon an originally granitic rock. The predominant mineral occurs in form of clear colourless scales of finely striated muscovite (potash-mica), the cleavage lines of which are frequently contorted; while the thin laminæ are seen to wrap round the lenticular masses of light-brownish felspar and clear colourless quartz. There are also in subordinate quantity a few scales of dark brown ferro-magnesian mica (biotite) inter-laminated with the muscovite and exhibiting their characteristic pleochroism. Under polarised light the muscovite displays brilliant mingled reds and greens; while the large purplish-red idiomorphic garnets with their strong contours and hexagonal outlines remain dark when revolved under crossed nicols. It will be also noticed that the garnets which stud the field without any definite arrangement are traversed by irregularly branching cracks. These are produced by an imperfect cleavage parallel to the rhombic dodecahedron.

Fig. 3.—This figure is intended to show the effects of dynamic metamorphism upon the mineral constituents

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of crystalline rocks, whereby a re-arrangement of the particles, with or without chemical changes, takes place in more or less parallel lines, and the rock becomes finely foliated, or, in other words, a *schist.*

Left-hand semicircle. **Chlorite-Schist,** Chemnitz, Saxony, × 15.—Here the chlorite, of green colour, is the dominant constituent, and is indifferently interleaved, so to speak, with dirty-brown felspar and colourless quartz; while specks of black opaque magnetite diversify the field of view. The following particulars for the determination of the minerals named are worth while remembering. Presuming that the section is a very thin one—say 0·001 of an inch—the clear quartz would change, when revolved under crossed nicols, from white or pale lemon to neutral tints; if thicker — say 0·005 in. — vivid chromatic polarisation will ensue. Under revolution of a single nicol the chlorite exhibits distinct pleochroism, changing from lighter to darker greens and *vice versâ.* The cloudy brown felspar denotes decay; while the magnetite gives reflections of metallic blue.

Right-hand semicircle. **Hornblende-Schist,** Bay of Nigg, Kincardineshire, × 20. — The green mineral which constitutes the bulk of this rock is seen to be drawn out into elongated particles, with a strong tendency to parallelism. It is unchanged hornblende, and several of the laths exhibit prismatic cleavages, which intersect at the characteristic angle of 124° 30′. Interfoliated there is plenty of a greyish-white felspar, and a less amount of clear colourless quartz.

Fig. 4. *Left-hand semicircle.* **Glaucophane-Schist,** Isle of Syra, The Cyclades, Greece, × 20.—Under the denomination of amphibolite-schist, this surpassingly

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beautiful rock exhibits peculiarities of structure which give rise to very striking appearances under the microscope. The affinities of the rock point to its origin as a coarsely crystalline diorite in which the felspar has given place by change to a greenish-yellow epidote; while the original hornblende has become metamorphosed into the variety glaucophane in elongated sky-blue crystals with marked parallel orientation, which exhibit, under revolution of a single nicol, pleochroic phenomena from peacock-blue to pale lilac; while the yellow epidote changes from yellowish-green to pale yellow. Red garnets, moreover, diversify an already gorgeous field of view, and are shown in the picture by their bold hexagonal outlines; while sundry interspaces are filled up with amorphous white calcite with vermiform green inclusions of the variety of chlorite called *helminth*. Transverse sections of the blue glaucophane crystals give the prismatic cleavages of hornblende—124° 30′.

Right-hand semicircle. **Amphibolite,** Pyrenees, × 20. —This picture portrays another phase in the evolution of schistose rocks, in which the dominant mineral is hornblende. The figure shows a field almost entirely composed of allotriomorphic hornblende compacted together, with here and there a bleb of quartz or a patch of felspar, both of which are colourless. The prismatic cleavages of the hornblende, intersecting at an angle of 124° 30′, are clearly shown in several of the individual crystals; while others, cut perpendicularly thereto, exhibit more or less parallel markings. The crystals are of a uniform pale green colour and are, of course, strongly pleochroic.

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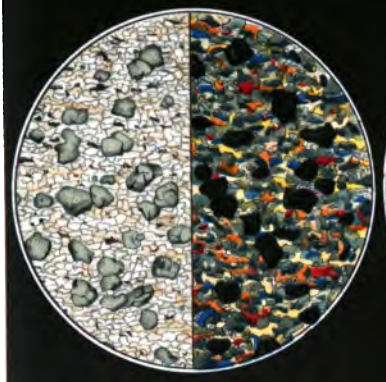

Fig. 1. GARNET-GRANULITE.
Chemnitz, Saxony, × 20.

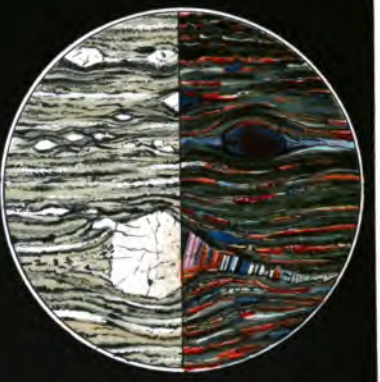

Fig. 2. CATACLASTIC SCHIST.
Strath Beag, × 20.

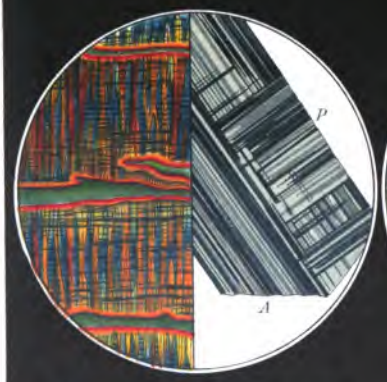

Fig. 3. MICROCLINE, × 20.
ALBITE, × 20.

Fig. 4. AGATE.
Montrose, Scotland, × 20.

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PLATE XV.

Fig. 1. Garnet-Granulite, Chemnitz District, Saxony, × 20.—The term granulite is used by English and German writers to signify a small group of even-grained rocks, which, without exhibiting any schistosity, have yet undergone a certain amount of dynamic metamorphism either during or after their consolidation. This is frequently manifested under crossed nicols, when an evident parallel orientation of the separate minerals may be witnessed; while, no less often in those granulites which exhibit this parallel structure, there are "strings" of fluid-pores disposed more or less at right angles to the parallelism which are indifferently developed in the grains of quartz and felspar which constitute the ground-mass of the rock,—these thereby indicating the main direction of the mechanical forces that have come into operation. The picture is divided by a diameter into a *left semicircle* shown under ordinary, and a *right semicircle* under parallel polarised light. The ground mass of even-grained texture is composed of about equal proportions of allotriomorphic grains of quartz and felspar, liberally flecked with small dark scales of mica (biotite); while the whole field is thickly studded with red garnets (pyrope) with bold contours of mostly hexagonal sections of rhombic dodecahedra in the left-hand field. As garnet belongs to the regular system, the sections in the polarised field, of course, extinguish in all positions. It is only in rare

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instances, due to profound metamorphism that garnets become *optically anomalous*, and display double refraction.

French petrographers call this rock *leptynite*, and reserve the term "granulite" for two-mica granites.

Fig. 2. Cataclastic Schist, rear of Great Thrust, Strath Beag, × 20.—Crush phenomena in rock masses are well shown by the example here depicted, the left-hand under ordinary and the right under polarised light. From an isolated specimen such as this, it is impossible to determine the original character of the rock, beyond the probability of its having been of igneous origin. The mechanical forces brought to bear upon the rock have taken a definite direction perpendicular to the long axis of the parallel lines of schistosity. The uncrushed fragments of minerals are seen to persist in the form of lenticles or eyes (*augenstructur*). The largest of these, crossed by the diametric division towards the bottom of the field of view, is all that remains of a former crystal of plagioclase felspar. This becomes apparent by the part of the "eye" under polarised light, which exhibits albite lamellation. Immediately above the lenticular patch and below it, all structure save schistosity appears to have been obliterated, so that the original components of the rock cannot be identified under the microscope. This represents the ultimate result of the cataclastic forces, and furnishes an example of the type of rock called *mylonite*, by Lapworth.

Fig. 3. *Left semicircle*, × 20. — **Microcline**, in a perfectly fresh condition, under crossed nicols, to reveal its otherwise hidden structure, and thus distinguish it from orthoclase felspar with which it is

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practically identical in chemical composition; while its general habit and crystal-angles also closely approximate those of orthoclase. This minute internal structure consists of compound polysynthetic twinning on both the *albite* and *pericline types*, and the two systems of twin lamellæ consequently give rise to a peculiar cross-hatching when (as shown by the figure), viewed in parallel polarised light. Again, unlike ordinary cross-twinning, the sets of lamellæ in microcline, when rotated into positions of extinction appear to be individually fusiform, instead of being bounded by parallel edges. Many microclines, moreover, as in the example here figured, are traversed by intergrowths of albite and sometimes of orthoclase. These are shown as horizontal bands or veinlets of albite in the figure, and are disposed in crystallographic relation to the matrix of microcline.

Unlike orthoclase, microcline crystallises in the triclinic system; but its cleavage angles come very close to those of the former mineral, *e.g.*—in orthoclase the cleavages parallel to the basal plane and the clino-pinacoid intersect at 90°, while in microcline, the corresponding basal and brachypinacoidal cleavages give an angle which differs therefrom by less than one quarter of a degree. The extinction angle of microcline is 15° 30′ measured to the edge formed by the basal plane and the brachypinacoid.

The cross-hatching coupled with spindle-shaped lamellæ are so characteristic that it has been called *microcline-structure*, and once seen, ought to enable the student to instantly detect this mineral in slices of rock under the microscope. Some authorities aver that ordinary orthoclase is nothing more nor less than

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microcline in which the cross-twinning has been carried to an ultra-microscopic degree of fineness: and some say that microcline probably results as a secondary effect of strain.

Microcline occurs typically developed as Amazonstone, a green variety, in the albitic granite of Pike's Peak, Colorado, where the cross-hatching can be seen upon the basal planes of the fine large crystals with the naked eye. These large crystals are of the usual orthoclase habit, and are frequently twinned in superior scale on the Baveno, Manebach, and Carlsbad laws. As a rock-constituent, microcline is generally milky, greyish-white, pinkish, or of flesh-red hue. It obtains usually with orthoclase and other felspars in many plutonic rocks,—notably as Amazonstone in the albitic granite of the Ilmen Mountains, Russia, and in Sutherlandshire, Scotland, and is the common variety of felspar in graphic granites. It may be studied to advantage as a rock-forming mineral in thin sections of the post-Ordovician granites of Leinster and the "grey Aberdeen granite" of Rubislaw; while it likewise occurs in gneisses and other crystalline schists, and has even been found in limestones altered by contact with Lherzolite. Microcline undergoes alterations precisely analogous to those which take place in orthoclase.

Right semicircle, × 20. **Albite,** under crossed nicols, to show A, polysynthetic twinning or lamellation on the *albite-type* and P, repeated twinning on the *pericline law.* When these two styles of twinning occur together, a cross-hatching arises, as shown towards the lower right hand part of the figure, but it will be observed that the sets of lamellæ exhibit *parallel* edges, and are not

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tapered like those of microcline. The albite type of twinning is characteristic of plagioclastic (lime and soda) felspars, which all belong to the triclinic system, and its lamellar or polysynthetic character, which is most frequently developed, may often be detected in ordinary light with the naked eye or a simple lens, in the form of fine lineations parallel to the brachypinacoid. This is the albite type, and under polarised light thin sections show a series of alternately dark and light bands, as at A in the figure, which are due to the simultaneous extinction of alternate lamellæ. When the lamellæ are developed at right angles to these, they constitute the pericline type of twinning, P, in the figure. The pericline type of twinning does not occur so frequently as albite lamellation in plagioclase felspars. In it, the twin axis coincides with the crystallographic axis, and its plane of composition is the so-called "rhombic section."

It is interesting to note, that when the species albite occurs as the dominant felspar in granites, as for instance, in the Mourne Mountains, Ireland, the Ilmen and Ural Mountains, Russia, and Pike's Peak, Colorado, U.S.A., the granite is usually the source of many rare minerals and precious stones, such as topaz, beryl, tourmaline, phenacite, etc.

Fig. 4. Agate, O.R.S. Lava, Montrose, Scotland, × 20.—The compound variety of silica known as agate occurs principally filling the amygdaloidal cavities of vesicular volcanic rocks. In the present instance, the specimen was obtained from an amygdule at the surface of a lava-bed of Old Red Sandstone age in the neighbourhood of Montrose. The *left-hand semicircle* shows the appearance of this mineral under ordinary

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light, in form of successive layers of variously coloured kinds of silica, *viz.*, chalcedony, amethyst, jasper and other shades of silica in alternating series. Under polarised light, (*right-hand semicircle*), the principal varieties of silica, which form the successive layers are seen to behave in optical unison; the orientation of the elements, mainly chalcedony and jasper in this instance, giving rise to an exceedingly beautiful mottled pattern in complimentary colours, which nevertheless shows vestiges of the concentric arrangement, and indicates a more intimate association of the several sorts of silica than can be detected under ordinary illumination.

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GLOSSARY.

ABYSSAL. — Equivalent to *Plutonic*, *i.e.*, rocks of deep-seated, fathomless, bottomless, igneous origin. Also applied to oceanic deposits.

ACCESSORY.—Minerals are called accessory when their presence or absence does not affect the character of the rock in which they occur; in contradistinction to *essential*. Accessory minerals, however, may be *original*, and of such importance as to indicate the conditions under which the rock was formed.

ACICULAR.—Slender and more or less pointed, like a needle.

ACID ROCKS. — Where the proportion of silica ranges above 60 per cent.

ADÉLOGÈNE.—So minutely granular as to appear almost structureless or invisible; *aphanitic* or *cryptomerous*.

ÆOLIAN.—From *Æolus*, the god of the winds, to denote structures formed by the influence of the winds; *e.g.*, "*Pélé's Hair*."

AGGREGATE POLARISATION.—The chequered or dappled appearance observed in mineral aggregates, when viewed between crossed nicols; due to the varying orientation of the individual particles, as frequently seen in grains of sand, and invariably in interstitial patches of secondary quartz.

ALLOCHROMATIC.—Literally, from some other colour. Applied to minerals which owe their colours to the presence of either mechanically suspended or chemically dissolved adventitious pigments, as in amethyst, fluor-spar, smoky-quartz, etc.

ALLOGENIC.—Minerals derived from rocks of prior origin to the one in which they are found; as quartz-grains in sandstone. Synonymous with Allothigenic and Allothigenous.

ALLOMORPHISM.—*See* Paramorphism.

ALLOTRIOMORPHIC.—Minerals which take their shapes from their surroundings were named allotriomorphic by ROSENBUSCH (*Mik. Phys. d. Massig. Ges.*, 1886, p. 11), in contradistinction to *idiomorphic* minerals, or those which develop their external forms freely. The terms *automorphic* and *xenomorphic* were used in the same sense as allotriomorphic by ROHRBACH (*Tschermak's Min. Mitth.*, VII., p. 18), and are adopted by Zirkel.

ALLOTROPIC.—The property assumed by some elements of existing in more than one form, as carbon in diamond and graphite.

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ALTERATION PHENOMENA.—Minerals and rocks are subject to many changes, principally due to the infiltration of meteoric water, and by thermal and dynamic influences.

AMORPHOUS.—Without crystalline form; structureless; homogeneous; possessed of equal elasticity in every direction.

AMYGDALOIDAL —Applied to volcanic rocks possessed of almond-shaped vesicular cavities filled with various infiltered products, which form *amygdules* of calcite, chalcedony, chlorite, delessite, zeolites, etc.

ANHEDRAL.—A term used by PIRSSON (*Bull. Geol. Soc. Amer.*, 1895, Vol. VII., p. 492) as a synonym for Allotriomorphic, Automorphic, and Xenomorphic.

ANISOMEROUS.—Applied to designate the granular structure in rocks where the grains are of various sizes.

ANISOTROPIC.—When a ray of light enters a crystal belonging to any other than the cubic system, it is usually divided into two refracted rays, neither of which need lie in the plane of incidence. Such crystals are said to be *doubly refracting* or *anisotropic*, and the angular divergence between the rays of refraction varies with the substances through which they pass, and differ according to different directions in the same crystal.

ANOGENIC.—Rocks which have not been produced where they are found, but have come up from below. Synonymous with Eruptive.

ANOMALOUS.—Crystals are *optically anomalous* when they differ in behaviour from the rest of their kind; as in garnets, which, having undergone pressure-strain, give weak interference-tints when rotated between crossed nicols.

ANTICLINAL.—Strata which dip away from an axis to form an arch or saddle.

APHANITIC.—*See* Adélogène, synonymous with Cryptomerous.

APOPHYSIS.—A vein or branch from the main mass—boss or dyke—of an igneous rock, such as the elvans and tourmaline-bearing granites.

AQUEOUS. — Rocks produced through the agency of water, whether by the deposition of mechanically suspended matter, or the precipitation of matter held in solution. Synonyms are: Catogenic, Derivative, Deuterogenic, Hydatogenic, Indigenous, Regenerated and Sedimentary.

ARENACEOUS. — Comparatively coarse detrital deposits of fragmental (clastic) accumulations, in the form of grains of one or more materials mechanically derived, and frequently supplemented by interstitial matter deposited in place; as in sandstones, grits, quartzites, breccias and conglomerates.

ARGILLACEOUS.—Clayey or composed mainly of clay, *i.e.*, hydrous silicate of alumina. When indurated, clays become *mudstones*, and when cleaved, are known as *slates*. NAUMANN used

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the terms "pelitic" and "pelolithic" as synonymous with argillaceous, to denote a texture like that of dried mud.

ASSISE.—In stratigraphical geology the term assise was adopted by the International Geological Congress at Bologna, in 1881, to signify the union of two or more strata or zones to form a bed or assise, which, however, is distinct from the next (lower or higher) beds, by a marked difference in its fossil remains, as exemplified by the Micraster assise of the Cretaceous system which includes the zones or horizons of *Micraster cortestudinarium* and *M. cor-anguinum.*

ASYMMETRIC. — In crystallography is synonymous with the triclinic system, where there is no plane nor axis of symmetry.

ATMOGENIC.—Changes caused by the reaction of vapour, notably in fumaroles.

AUGENSTRUCTUR.—In the study of cataclastic phenomena, the mechanical forces, having a definite direction frequently cause uncrushed fragments to assume a lenticular or eye-shaped form, with their long-axes at right-angles to the maximum pressure. Hence the term "augenstructur" or "eye-structure."

AUSWEICHUNGSCLIVAGE. — In his work on the structure of mountain-chains, HEIM (*Mechanismus der Gebirgsbildung*, Bd. II., p. 53) employed this term to denote the advanced stage of microscopic puckering, which, by subsequent rupture, has resulted in a fine cleavage or jointing, called by British petrologists "strain-slip" cleavage, and recorded as the second type of cleavage by SORBY (*Q.J.G.S.*, Vol. XXXVI., *Proc.*, p. 72).

AUTHIGENIC. — Also written "authigenous." In sedimentary rocks of the nature of sandstones and grits, it will be found that the derived, clastic or allothigenous particles are bound together by means of a cementing substance formed *in situ.* This interstitial cement may originate by the recrystallisation of detrital matter, by the solution and redeposition of material from the clastic grains, or by the infiltration of extraneous substance, and was therefore termed "authigenic" by KALKOWSKY (*Neues Jahrbuch für Mineralogie*, 1880, Bd. I., p. 4).

AUTOCLASTIC.—A term proposed by H. L. SMYTH (*American Journ. Sci.*, 3rd Ser., XLII., p. 331) for certain rocks formed by the agency of crush phenomena. The original rock lying under too light a load to become plastic, has, by being subjected to enormous crushing, been broken into fragments. The fragments in their turn may be thrust along shear-planes, and their angles thus more or less rounded off; so that the ultimate results closely resemble aqueous conglomerates or breccias, from which, however, they can be distinguished by

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the local derivation of their materials, and the absence of the characteristic water-worn surfaces of the component fragments. "Crush-conglomerates" and "crush-breccias," are therefore obviously *autoclastic.*

AUTOMORPHIC.—Synonymous with Idiomorphic.

AXIOLITIC.—In many rhyolites, elongated and sometimes branched spherulitic bodies are developed, and the fibres of which they are composed, instead of radiating from a centre, are found to diverge from a line such as a crack. To this modification of the spherulitic structure ZIRKEL (*Micr. Petrog. 40th Parallel*, p. 173) has given the name *axiolitic.*

AXOTOMOUS.—Capable of being cleaved in one direction only.

AZOIC.—Literally lifeless. Rocks of purely inorganic origin. Synonymous with Agnotozoic, Archæan, Pre-Cambrian.

BANDED.—Arranged in more or less parallel bands, which are manifest by reason of their variations of colour, texture, structure or composition.

BANK.—A bed of rock distinguished among other associated beds by being either thicker or more coherent.

BASAL PLANE.—In crystallography the plane which cuts the vertical morphological axis at right angles and lies parallel to the lateral axes in the tetragonal and hexagonal systems; while in the rhombic, monoclinic and triclinic systems it coincides with one of the three pinacoidal planes and lies parallel to the two lateral axes.

BASALTIC.—Synonymous with "Columnar" structure, where the rock is divided into prismatic joints or columns, as typically represented by basalts and basic lavas generally.

BASE.—According to ZIRKEL (*Mikros. Beschaff. der Min. und Ges.*, 1873, p. 268) this term should be reserved for the glassy or felsitic unindividualised portions of the ground-mass in porphyritic rocks.

BASIC.—Applied by BUNSEN to rocks containing under 60 per cent. of silica.

BED.—In modern geotectonic geology the name "bed" is defined to be constituted by that part of a sedimentary deposit which is included between two more or less distinct divisional planes which are due to the mode or nature of the successive deposits. A bed may be built up of many *layers* or *laminæ.*

BELONITE.—Coined from the Greek word for dart or arrow, by ZIRKEL, to signify a needle-shaped crystallite.

BELONOSPHERITE.—Used by VOGELSANG (*Die Krystalliten*, 1875, p. 134) to indicate the fibrous radial structure in spherulitic or concretionary bodies, as in the orbicular diorite called Napoleonite, where the radiating needles are composed of anorthite and hornblende.

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BIAXIAL. — Possessed of two optic axes, as in the rhombic, monoclinic and triclinic systems of crystallography.

BIFURCATED. — Terminated by two prongs, as in the felspar microlites of many vitreous rocks.

BISECTRIX.—In crystals of the rhombic, monoclinic and triclinic systems, which are the only ones possessed of a plurality of optic axes, the intersection of two optic axes, of course, gives rise to four angles, of which the alternate angles are necessarily equal. These alternate angles are acute and obtuse and the lines bisecting them are therefore termed the *acute bisectrix* and the *obtuse bisectrix* respectively. Now, although the optic-axial angles frequently vary in minerals, the bisectrices are usually very constant; so that in practical work it is more important to determine the position of the bisectrices with reference to the crystallographic axes than to rely upon the angles made by the crossing of the optic axes themselves.

BINARY.—Literally two-fold. When a rock contains two forms of one kind of mineral it is sometimes called "binary;" as in binary or two-mica granite, which contains both ferro-magnesian (biotite) and potash (muscovite) mica.

BIREFRINGENCE.—Or double refraction of crystals, is of specific value in the determination of minerals other than those belonging to the cubic or tesseral system. All doubly refracting crystals when examined between crossed nicols do not extinguish except when placed in certain definite positions, but give rise to *polarisation* or *interference-tints*, which vary in brilliancy and intensity of colours according to the nature of the mineral, the direction of the section relatively to the ellipsoid of optic elasticity, and the tenuity of the section under examination.

BLADE.—A long narrow plate or lamella. *Bladed-structure* is well seen in serpentine derived from hornblende; the alteration of the hornblende into serpentine having proceeded along the cleavage planes or lines of least resistance.

BLEACHING.—In the study of rocks decoloration is often manifested where heated volcanic vapours rise through tuffs or lavas and transform them into white clays. GEIKIE (*Text-book of Geology*, 1903, p. 768) also cites a case in Arran where "a zone of decoloration ranging from 5 or 6 to 25 or 30 feet in width runs in the red sandstone along each side of many of the abundant basalt-dykes. This removal of the colouring peroxide may have been effected by the prolonged escape of hot vapours from the cooling lava of the dykes. Had it been due merely to the reducing effect of organic matter in the meteoric water filtering down each side of the dyke it ought to occur as frequently along joints in which there has been no ascent of igneous matter."

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BOGENSTRUCTUR.—A termed introduced by MÜGGE to signify the occurrence of fragments with concave contours (*see* RUTLEY, *Q.J.G.S.*, 1902, Vol. LVIII., p. 30) in rhyolitic tuffs, thereby serving to point to the origin of the rock and separate it conclusively from the rhyolites or true acid lavas.

BOMB.—Ejected semi-molten matter from the neck of a volcano, which, in being whirled through the air, assumes a spheroidal shape and solidifies in descending to the surface of the earth. Bombs range in size from a few inches to several feet in diameter, and may be hollow, solid, usually cellular or pumiceous, or formed of a block of stone as nucleus with an external coating of lava.

BOSS.—Any projecting irregularly-shaped mass of rock, usually of igneous origin, but also of stratified rock protruding through beds of more recent origin.

BOTRYOIDAL.—Like a bunch of grapes in external form; commonly seen in specimens of dolomite and hæmatite.

BRACHYDIAGONAL.—In crystallography the shorter of the two lateral axes in the rhombic and triclinic systems.

BRACHYPINACOID.—The plane which lies parallel to the vertical axis and the shorter of the two lateral axes in the rhombic and triclinic systems of crystals.

BRECCIATED.—Resembling a breccia in structure, *i.e.*, where the clastic components of the rock, which may be either fine or coarse, obtain in *angular* fragments.

BRECCIATION.—Among cataclastic structures (*see* KJERULF, *Nyt. Mag.*, XXIX., pp. 3, 269) in regions of great mechanical disturbance, the rock-mass may break up along definite surfaces of sliding, and the material bordering the fracture is frequently ground down by friction into angular fragments which are subsequently compacted together to form a "friction-breccia" *in situ*. When the fragments are much rubbed and rolled over, their angles get worn off, and eventually a new structure, called a "friction-conglomerate," is formed.

CALCAREOUS.—Composed of or containing a marked proportion of carbonate of lime.

CALCIFEROUS.—Lime-bearing rocks.

CALCINATION.—By the over-powering heat evolved from erupted rocks, especially of basalts, dolerites and the like, the adjacent rocks are often calcined and either completely or partially melted and resolidified into vitreous or slaggy substances.

CANCELLATED.—Cross-hatched or latticed, as shown by the microscopic structure of most serpentines, the cleavage-cracks of cross-sections in pyroxenes and amphiboles, and in some

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triclinic felspars when twinned simultaneously on the albite and pericline types.

CARBONACEOUS.—Bearing carbon in some form or other, such as coal or graphite, and therefore usually of a black, brown, or dark colour.

CATACLASTIC.—KJERULF'S term to denote structures in rock-masses which have been subjected to crush phenomena along lines of fracture or movement such as faults and thrust-planes. Under the microscope the crushed mineral particles can frequently be seen compacted together and not recrystallised as in the granulitic structure. The ultimate result of complete cataclastic processes has been called *mylonite* by LAPWORTH (*Introd. Text-book of Geology*, 12th ed., p. 107).

CATOGENIC.—As distinguished from *anogenic* or eruptive rocks, the term catogenic is sometimes employed by geologists to indicate the sedimentary origin of rocks, or rocks which have been deposited—aqueous.

CAUSTIC-ACTION.—A feature usually manifested in cases of contact-metamorphism, where certain minerals of one rock may be partially or wholly dissolved out at the line or in the neighbourhood of the junction, and incorporated with or reconstituted in the other rock.

CELLULAR.—This structure is notably caused in igneous rocks by the expansion of steam in the molten magma, and is characterised by the presence of irregular spheroidal or ellipsoidal cavities, as in pumice, scoriæ and slags.

CELYPHITIC.—Plutonic rocks frequently show nuclei of the earlier formed minerals enveloped in bands or borders of minerals that have consolidated later on. This is the *kelyphit-structur* of SCHRAUF. It is well shown by the *corona* or band of hypersthene which sometimes surrounds the olivines or iron-ores in gabbros and norites, in the shell encasing the garnets of pyrope-bearing peridotites and in many eclogites.

CENTRIC.—Ocellar or centric structure is the name applied to stellately disposed microlites, granules or crystals around a grain or group of grains as nucleus, and occurs in both volcanic and banded crystalline rocks.

CHATOYANT.—A varying lustre, typically exhibited by the cat's-eye, is attributed to the presence of ultra-microscopic particles.

CHERTY.—Resembling chert in texture or mode of occurrence, *i.e.*, in layers or nodules of impure calcareous forms of flint.

CHILLED.—The glassy or finely-textured edges or borders of an intrusive mass of rock, due to rapid cooling of the molten magma at those parts, are said to be chilled.

CHLORITIC.—Bearing one of the chlorite-minerals; usually the result of decomposition of biotite, hornblende or augite.

CLASTIC.—Rocks constituted by derived or fragmental particles,

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such as sandstones, breccias, tuffs, and fragmental rocks produced by earth-movements.

CLAVATE. — Club-shaped or gradually thickening towards the top, as in the "pegs" of the *peg-structure* met with in melilite.

CLEAVAGE.—A physical property possessed by minerals, whereby they separate along definite planes which lie parallel to the faces of one or more of the crystalline forms of the mineral. In rocks, cleavage denotes a fissile structure superinduced by pressure; the cleavage planes being independent of the bedding, and developed at right angles to the direction of the pressure. When secondary minerals are formed and remain *in situ* along the planes of cleavage, the structure known as *cleavage-foliation* results.

CLINOBASIC. — Synonymous with Monoclinic, Clinorhombic, Oblique, Monoclinohedral, Monosymmetric.

CLINODIAGONAL.—The axis which is inclined to the vertical axis in the monoclinic system of crystallography.

CLINODOME, CLINOPRISM, CLINOPYRAMID.—*See* Dome, Prism, and Pyramid.

CLINOPINACOID. — One of the three principal crystallographic planes in the monoclinic system, which lies parallel to the vertical and the inclined axis, and is coincident with the plane of symmetry.

CLOSE-JOINTS-CLEAVAGE.—DR SORBY'S term for *Ausweichungs-clivage*, and the *strain-slip-cleavage* of PROF. BONNEY.

COKING.—By enormous heat evolved from eruptive masses, notably basalts and kindred volcanic rocks, contiguous structures may be actually calcined, coked or even melted.

COLLOID.—A stony yet truly amorphous mineral deposited from aqueous solution, as opal, which is a true colloid silica and has never been met with in crystalline form. Silica is the most frequent mineral in Nature to take the colloidal form; notably as pseudomorphous matter replacing the calcareous tests of *Foraminifera* in rocks of oceanic origin.

COLUMNAR.—When a rock is traversed by two or more systems of "master joints," a columnar structure is developed. This is well exemplified by igneous rocks and reaches its best development in basalts, such as those of the Giant's Causeway and Fingal's Cave.

COMPACT.—In megascopic examinations, rocks are said to be of compact texture when their closely-grained particles are too minute to be distinguished by the naked eye.

CONCHOIDAL.—When the fracture of a mineral or rock assumes a concave, convex or rounded shell-like surface, as in quartz, obsidian, flint and other highly compact stones.

CONCRETIONARY.—Minerals or rocks formed by the aggregation

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of particles around a nucleus to produce a rounded nodule or irregularly-shaped lump.

CONE-IN-CONE. — A peculiar kind of concretionary structure, manifested in the form of small cones one within the other, whether originally deposited as such, or superinduced by the influence of pressure upon concretions during the course of their formation.

CONFORMABILITY.—When rocks of either igneous or aqueous origin have been laid down continuously without disturbance, and are possessed of the same dip and strike, the beds are said to be *conformable.*

CONGLOMERATIC.—Sedimentary rocks formed of rounded pebbles cemented together by a variable paste of sand, clay, lime, or other matter.

CONTACT-METAMORPHISM.—Alterations in rocks produced by the intrusion through them of igneous rock-matter. At and for some distance from the junction, the changes induced in the surrounding rocks are called *exomorphic,* while those observable in the intrusive rock itself are styled *endomorphic.*

CONTEMPORANEOUS.—Interbedded igneous rocks and segregation veins are described in petrology as contemporaneous, synchronous, or of the same age.

CONVERGENT-LIGHT.—By means of a substage condenser the rays of polarised light from the lower nicol's prism fitted to the microscope are made to converge within the crystal under examination. Upon introduction of the analyser and the crossing of the nicols, interference-figures may be seen through the tube of the microscope without its eye-piece, or by the interposition of a Bertrand-lens, to enable the observer to determine the uniaxial or biaxial character of doubly refracting minerals.

CORALLOIDAL.—Shaped like a coral, as in the curious aragonite or *flos ferri* of Eisenerz in Styria. The coralloidal aspect of pisolitic and oolitic rocks, moreover, led the older geologists of early-microscope days to regard those structures as fossil remains, *e.g.*, the pisolitic limestone of Colwall Copse in the Malvern Hills was accounted to be the relic of a *Stromatoporoid.*

CORONA-STRUCTURE—*See* Celyphitic-structure.

CORROSION.—Crystals that have already been formed are sometimes destroyed or corroded at their margins, and even occasionally to their cores, by the surrounding molten magma of the rock before its final consolidation.

CORRUGATED.—Applied in petrography to shrinkage effects, and to the wrinkled or crumpled condition of foliated rocks.

COULÉE.—A lava-flow or stream; a phase in the effusive period of the consolidation of igneous rocks.

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COUNTRY-ROCK.—A miner's term for the rock through which mineral or metalliferous veins run.

CRENITIC.—Employed by STERRY HUNT for his theory to account for the origin of crystalline schists by the agency of springs bringing up mineral matter in solution from deep-seated sources.

CRYPTOCLASTIC.—Denotes the true clastic, derived or fragmental nature of exceedingly fine-textured sedimentary rocks, such as compact mudstones and other argillaceous deposits.

CRYPTOCRYSTALLINE.—When the component crystalline particles are so diminutive as to even defy resolution under the microscope. Between crossed nicols such textures show aggregate polarisation. They may be original or due to secondary changes, such as devitrification.

CRYPTOGRAPHIC.—A term introduced by HARKER to indicate the ultra-microscopic phase in micrographic and micro-spherulitic structures to be met with in certain granophyres.

CRYPTOMEROUS.—Finely textured. Synonymous with *adélogène* and *aphanitic*.

CRYPTOPERTHITIC.—Having an obscured perthitic structure. It occurs as soda-orthoclase in the rock called "Laurdalite" by BRÖGGER (*Die Silur. Etage*, Christiania, 1882, p. 273).

CRYSTALLINE.—In petrography the term crystalline is applied to any mineral aggregate composed of crystallised substances, whether they obtain in the form of perfect crystals or merely as grains exhibiting the physical properties of crystals.

CRYSTALLITE.—A term introduced by SIR JAMES HALL to indicate the lithoidal substance obtained by him after fusing and gradually cooling various "whinstones." In modern petrology the word is generally taken to signify those incipient forms of crystallisation which, although of microscopic dimensions, assume a variety of well-defined shapes, but the optical properties of which are insufficient to enable one to determine their mineral species. Thus, they may be described as globulites, margarites, longulites, trichites, stellites and belonites; but not as *microlites*, the latter being reserved for incipient crystals of known minerals, which exert a definite action on polarised light.

CRYSTALLOGENESIS.—The formation and growth of crystals.

CRYSTALLOGRAPHIC.—Crystals are all referable to one or other of thirty-two groups, each of which is characterised by its special symmetry; and these groups are classified under six crystallographic systems respectively called the Cubic, Hexagonal, Tetragonal, Rhombic, Monoclinic and Triclinic.

CRYSTALLOID.—In microscopical petrography VOGELSANG reserved this name for minute bodies which are intermediate in development between crystallites and microlites, viz., bodies

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which, although devoid of crystallographic contours, are yet possessed of power to react on polarised light.

CUBE.—Gives its name, and is one of the simplest forms of the *cubic* or *regular* crystallographic system. It is bounded by six equal square faces, each of which cuts one axis at right angles and lies parallel to the other two, thereby coinciding with the three principal planes of symmetry of its system. The cube may also be styled a hexahedron.

CUBIC SYSTEM.—Called also the Regular, Tesseral, Octahedral, Tessular, Isometric or Monometric system. It is possessed of nine planes of symmetry; while the forms belonging to the system are referable to three equal and similar axes, disposed at right angles to one another.

CUBOID.—Resembling a cube. The term is applied to the roughly rectangular blocks of certain igneous rocks, such as granite, proterobase, etc., which are formed by their weathering along an intersecting system of horizontal and vertical joint-planes.

CUMULITES.—These are cloudy patches, to be observed in many glassy volcanic rocks, due to the aggregation of vast numbers of the spheroidal crystallites called *globulites*.

CUNEATE.—Also called cuneiform or wedge-shaped, as in well-developed crystals of sphene.

CUSPIDATE.—Pointed like the cusp of a canine tooth, as often shown by sections of twin crystals of rutile.

DAMASCENED.—A term introduced by RUTLEY to describe the structure shown in some obsidians, *e.g.*, the red obsidian from Tolcsva in Hungary, "in which streaks or threads of glass are contorted in a confused manner which somewhat resembles the markings on Damascus sword-blades or the damascening on gun-barrels."

DECOMPOSITION.—Under the microscope, rocks of all kinds show signs of every stage of decomposition, culminating in a complete alteration of the original rock-mass. The presence of many minerals, indeed, point to such changes through the agency of meteoric water, and degradation products take the form of serpentine, chlorite, epidote, limonite, calcite, scales of paragonite, and substances of doubtful composition, called, for the sake of convenience, viridite, ferrite and opacite.

DEDOLOMITISATION.—By contact-metamorphism dolomite and dolomite-bearing rocks are prone to be deprived of their original character by the dolomite being reduced to the condition of calcite, while its magnesia enters into the formation of new minerals.

DENDRITIC.—The divisional planes of finely textured rocks are frequently the seat of arborescent deposits, most commonly of earthy oxides of manganese or of iron. Sometimes these

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plant-like aggregations penetrate through the substance of the rock itself, as in the curious case of the Cotham or so-called "landscape-marble."

DERIVED.—*See* Aqueous.

DETRITAL.—*See* Clastic.

DEUTEROGENIC.—Synonymous with Aqueous.

DEVITRIFICATION.—When an originally glassy substance takes on a stony or cloudy character by reason of the development of infinitesimal particles (crystallites and microlites), it is said to be devitrified. This change may take place either during or after the consolidation of the mass.

DIACLASE.—*See* Joint.

DIALYTIC.—NAUMANN'S term for rocks derived from the chemical decomposition of other rocks, *e.g.*, clay, kaolin, etc. Also called *Cimmatic.*

DIASTROPHISM.—MAJOR POWELL'S name to indicate the various processes which operate to deform the crust of the earth, such as fracture, plication, elevation and subsidence.

DICHROISM.—*See* Pleochroism.

DIFFERENTIATION.—The same mass of molten magma, may upon its consolidation, vary considerably from place to place, being decidedly acid at the centre and basic at its margins. In dolerites and basalts, moreover, the rocks commonly change in character from a tachylytic selvage, through a porphyritic andesite to a thoroughly holocrystalline dolerite at the centre of the dyke.

DIP.—Rocks of sedimentary origin are always deposited in an approximately horizontal position; when, however, they have been disturbed by earth-movements, they usually assume an inclined position, which is termed the dip, and this dip is indicated by measuring the angle made by the plane of the bed with the plane of the horizon.

DISAGGREGATION.—When rocks of an originally compact character are rendered friable as the result of contact with intruded material, as in the case of the red granite of Ronez Point, Jersey, by contact with the intrusive proterobase, or *vice versâ*, as in the crumbling away of dolerite into the so-called "white-trap" by its intrusion through the coal measures.

DISOMATIC.—SEIFFERT and SÖCHTING'S name to signify that a crystal and its inclusions belong to different mineral species.

DOLOMITISATION.—A metasomatic change in calcareous rocks, whereby the calcite is converted into dolomite by the replacement of half of its lime by magnesia.

DOME.—A plane of symmetry, of itself, gives rise to a dome. The dome may be regarded as a lateral prism in that it runs parallel to a lateral instead of to the vertical axis of a crystal. Domes, moreover, may be treated as special cases of pyramids,

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i.e., those in which the pyramidal faces intersect one of the lateral axis at an infinite distance.

DOME-VOLCANOES.—VON SEEBACH'S type to indicate a volcanic hill free from evidences of craters or chimneys, probably due to the less fusible and more viscid nature of the lava, than in that of bedded-volcanoes.

DOUBLE-SPHERIC.—A structure in rocks in which several small spherulites are disposed in concentric layers around a real or imaginary nucleus to form a large spheroidal aggregate.

DRUMLINS.—Glacial drift, which collects to form long ridges in the direction of the ice-movement, especially around the mountainous regions of dispersion.

DRUSE.—A cavity in rocks, upon the walls of which crystals are developed. *See* Miarolitic.

DYKE. — A wall-like mass of igneous rock intruded through surrounding structures in a more or less vertical direction. The dyke-rocks of ROSENBUSCH (*Gang-gesteine*), intermediate between the plutonic and volcanic series of rocks, correspond with the now generally accepted division of hypabyssal rocks so called by BRÖGGER.

DYNAMIC METAMORPHISM.—Changes (either structural, mineralogical, or both) produced in rocks by mechanical agencies, such as pressure, earth-movements, shearing, etc.

EFFLORESCENCE.—Incrustations of saline minerals, often of considerable magnitude, are formed upon the surface of the soil by water which rises by capillary attraction from below to evaporate above and leave these products of efflorescence behind, as in the Great Salt Lake region of Utah, U.S.A.

EFFUSIVE.—Erupted rocks or parts of such as have consolidated after having been poured out upon the surface of the earth.

ELASTICITY. — With regard to the optic elasticity of crystals, HARKER, in his *Petrology for Students*, notes: "All the optical properties of a crystal are related to three straight lines conceived as drawn within the crystal at right angles to one another (the *axes of optic elasticity*), and to a certain ellipsoid having these three straight lines for axes (the *ellipsoid of optic elasticity*). The positions of the three axes may vary in different minerals, but they must always conform to the symmetry proper to the system; and the same is true of the relative lengths of the axes of the ellipsoid. The plane of section of any slice cuts the ellipsoid in an ellipse, the form and position of which depend upon the direction of the section (*ellipse of optic elasticity*), and the axes of extinction are the axes of this ellipse."

ELUVIAL.—Among æolian or wind-formed deposits, TRAUTSCHOLD applied the name *eluvium* to wind-borne dust which settles on

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ground covered with vegetation, and is thereby held *in situ* as a deposit.

ENANTIOMORPHIC.—In crystallography hemihedral and tetartohedral crystals devoid of a plane of symmetry are termed *enantiomorphic.*

ENDOMORPHIC.—Minerals enclosed within other minerals. Also used by FOURNET to indicate contact-metamorphism in the erupted rock. Sometimes called *endogenous.*

ENTOOLITIC.—GÜMBEL'S name for oolitic grains which have been formed without nuclei, as in the hot-springs of Carlsbad, where the growth originates in a film of carbonate of lime being formed around floating bubbles.

EPIGENETIC.—When secondary minerals are formed by processes of alteration in rocks.

ERRATIC.—Applied to stray blocks of rock which have been detached from the parent mass and transported to their present sites, usually by the agency of ice.

ERUPTIVE.—Synonymous with Igneous, but sometimes restricted to rocks which have reached, if not overflowed, the surface of the earth.

ESSENTIAL.—Minerals are said to be essential when their absence would materially alter the typical character of the rock.

ESTUARINE.—Deposits and rocks formed from those deposits at the mouth of a river.

EURITIC.—Where the crystals are of such small dimensions as to require resolution under the microscope, as typically developed in eurites. Synonymous with Microgranitic.

EUTAXITIC.—When a lava flow results in a rock which changes rapidly in texture in a direction normal to the direction of flow. The term has also been applied to banded igneous rocks which have not flowed over the surface.

EVEN-GRAINED.—In contradistinction to porphyritic the even-grained structure (*körnig* of ROSENBUSCH) is typical of plutonic rocks.

EXFOLIATION.—The separation of scales or layers from rocks, frequently produced by weathering.

EXOMORPHIC.—In cases of contact-metamorphism exomorphic change takes place in the rock through which the molten mass passes.

EXOOLITIC.—GÜMBEL'S term to denote the formation of oolitic grains around nuclei.

EXTINCTION.—Between crossed nicols a mineral section extinguishes or becomes dark and obliterated when its axes of depolarisation coincide with the principal planes of the nicols. The angle of extinction of any mineral section is measured between a position of extinction (axis of depolarisation) and the trace of some definite crystallographic plane.

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EYE-STRUCTURE.—In the dynamic metamorphism of rocks the mechanical forces frequently cause uncrushed fragments to assume the shape of an eye or lenticle, with its long axis perpendicular to the direction of maximum pressure. *See* Augenstructur.

FACE.—The plane surfaces which bound crystals are called its faces.

FALSE-CLEAVAGE.—Of frequent though local occurrence in fine-grained rocks, this sometimes assumes a parallel disposition of microscopic faults, which occasionally occur in a regular system of diminutive folds, and give the rock a tendency to split along definite planes. *See* Close-joints-cleavage, Strain-slip-cleavage and Ausweichungsclivage.

FASCICULAR.—Arranged in fascicles, tufts or little bundles of needles or fibres.

FAULT.—By reason of movements the crust of the earth has not only been folded and corrugated, but fractured in all directions. These fractures may remain in their original condition of simple fissures; but, when there has also been a vertical displacement and one side of the rent gets shifted relatively to the other, it is called a *fault*. Synonymous with Dyke, Heave, Paraclase, Throw, Trouble.

FELSITIC.—A somewhat loosely applied term. Most petrographers nowadays apply the name to the macroscopically homogeneous ground-mass of the acid-intrusive series of rocks, which, when examined under the microscope, reveal a micro- or crypto-crystalline structure. When this structure is not reacted upon by polarised light it is termed *microfelsitic*.

FELSOPHYRIC.—When the ground-mass of certain quartz-porphyries is mainly microfelsitic, with only subordinate crypto-crystalline patches.

FELSPAR-MOSAIC.—By dynamic metamorphism the felspar of rocks is generally reconstituted in form of granular aggregates like a mosaic, the separate tesseræ of which are variously orientated.

FELSPATHIC.—Composed mainly of felspar; usually applied to indicate the nature of the ground-mass of rocks.

FELTED.—When diminutive crystals (microlites) are compacted together indiscriminately, like the fibres of felt, as in the *hyalopilitic* ground-mass of typical andesites.

FIBROUS.—Constituted by fibres or thread-like structures of one or more minerals; either regularly disposed and parallel, as in satin-spar; or more or less irregular and tufted, as in asbestos.

FISSILE.—Capable of being split into thin leaves. Lamination,

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jointing, cleavage, shearing, foliation, and pronounced flow-structure are the principal causes of fissility in rocks.

FLASER-STRUCTURE. — NAUMANN'S name for the minute inconstant banding and lenticular disposition of particles developed by mechanical agencies, as in the "Flaser-gabbros" of Saxony, Aberdeenshire, etc., and certain crystalline schists.

FLUID-CAVITIES.—*See* Inclusions.

FLUIDAL-STRUCTURE. — Also called *Fluxion-structure.* The results of differential movements in the molten magma, shown by differently coloured bands in thoroughly glassy rocks, by the linear and parallel arrangement of crystallites and microlites in rhyolitic types, and by the smaller and later crops of crystals sweeping round the larger first-formed phenocrysts, as in typical porphyritic basalts.

FOLIATION.—DARWIN'S term to denote the disposition of mineral particles in parallel, sometimes wavy layers, which endow the rock with its schistosity or tendency to split, as in the crystalline schists.

FORMATION.—A dual meaning is attached to this word. In stratigraphical geology, a formation is understood to signify a group rather than a system of rocks, characterised by their fossil contents, but not necessarily separated by any sharp line of demarcation from the formations above or below it, as in the Permian, Carboniferous, Devonian, etc. To a lesser degree lithological characters are also to be taken into account. Secondly, the word formation may be used with reference to the origin of the rock, such as oceanic, lacustrine, volcanic, etc.

FRACTURE. — The surface shown when a mineral or rock is freshly broken depends upon its texture, and is described as smooth, rough, hackly, conchoidal, slaty, etc.

FRAGMENTAL.—*See* Clastic.

FRIABLE.—Capable of being easily reduced to a powder, as in dry clay, chalk, etc.

FUSIFORM.—Spindle-shaped, as in the lamellæ revealed between crossed nicols in sections of microcline.

FUSIBLE.—Most minerals when heated pass from the solid into the liquid state, and this form of pyrognostic reaction is sometimes useful for purposes of determination. Upon this property VON KOBELL founded his still accepted scale of fusibility as follows: 1. Stibnite, which fuses in even a candle-flame. 2. Natrolite and Chalcopyrite fuse to globules when splinters are subjected to the flame of a candle. 3. Almandine-Garnet fuses in large pieces before the blowpipe. 4. Actinolite fuses in small fragments only before the blowpipe. 5. Orthoclase under the blowpipe becomes merely rounded. 6. Bronzite, when in very fine splinters, fuses with great difficulty before

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the blowpipe. 7. Quartz is infusible before the ordinary blowpipe. Of course this scale does not apply to the intense temperatures producible by the oxyhydrogen flame or electric arc, under which all minerals succumb; but many minerals, especially silicates, remain infusible when heated in the flame of an ordinary blowpipe.

GANG-GESTEINE.—ROSENBUSCH'S name for rocks which occupy an intermediate place between those of deep-seated and superficial consolidation. Synonymous with Hypabyssal.

GAS-CAVITY.—Inclusion in any crystal filled with gas, determinable under the microscope by its bold borders, which are due to the great difference between the refractive indices of the contained gas and the solid substance which incloses it.

GEODE.—Nodular bodies, either hollow or filled with crystals.

GLASS-CAVITY.—Inclusion in a crystal filled with clear or devitrified glassy-matter. Its contours are not so strongly marked as inclusions of liquids or gases.

GLASSY.—Resembling glass in being amorphous and isotropic. Minerals of a glassy nature may be of either aqueous or igneous origin, such as colloid silica and the uncrystallised residuum of the ground-mass in basalts, or the bulk of the substance in vitreous rocks—pitchstones and rhyolites.

GLAUCONITISATION.—The calcite or aragonite of organisms in calcareous and calcareo-arenaceous deposits is replaced by green silicates, glauconite grains and casts in marine sandstones, limestones and oceanic "green-muds."

GLIDING-PLANE.—Strain-phenomena in crystals are evidenced at times by gliding-planes, which are definite directions in which the molecules glide over one another by reason of the suitably directed pressure.

GLOBOSPHERITE.—Applied by VOGELSANG to spherulites composed of radially arranged globulites.

GLOBULITE.—A crystallite of spherical shape.

GLOMERO-PORPHYRITIC.—JUDD'S name for porphyritic crystals which are made up of an aggregate of minerals. These hypidiomorphic aggregates sometimes present idiomorphic outlines towards the surrounding rock-mass.

GRANITIC.—Resembling granite in structure by being composed of allotriomorphic crystals of more or less uniform size. Synonymous with Granitoid.

GRANITISATION.—The injection of granitic material through other rocks, not only on a large scale but down to even microscopic dimensions.

GRANITO-TRACHYTIC.—Used by VON LASAULX as synonymous with the Ophitic structure.

GRANOPHYRIC.—A characteristic structure of hypabyssal rocks,

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in which the quartz and felspars of the ground-mass have become intimately intergrown by reason of simultaneous consolidation. Synonymous with Micrographic, Micro-pegmatitic.

GRANOSPHERITE.—Applied by VOGELSANG to irregular aggregates of crystalline grains, compacted into spherulites.

GRANULAR.—Composed of rounded or sub-angular clastic grains of approximately equal sizes, as in sandstones, or of irregular crystalline particles, as in granites and marbles.

GRANULATION.—The disintegration into granules of the mineral constituents of rocks that have been crushed and re-consolidated. *See* Cataclastic.

GRANULITIC.—MICHEL-LÉVY'S term for rocks composed of grains of approximately uniform sizes, each of which is independently orientated. This structure is commonly found in cataclastic granitoid rocks, where the crystals have been crushed and then consolidated. PROF. JUDD considers that the *granulitic* structure of the augite in relation to the felspars of certain diabasic rocks is due to a movement in the mass towards the final stage in its consolidation.

GRAPHIC.—In veins outside a large intrusive mass of granite the felspar and quartz frequently consolidate simultaneously in such a way as to tend to an orientation of their longer axes in one direction. Such intergrowths when cut transversely bear a resemblance to Hebrew inscriptions and have therefore been called *graphic*, as in graphic-granite or pegmatite. It is classed by ZIRKEL, along with oolitic, spherulitic, etc., under the heading "Implication-structure."

GRITTY STRUCTURE.—Typically developed in the grits, where the clastic grains are not rounded, but angular and often sharp.

GROUND-MASS. — The matrix of a rock in which the earlier porphyritic crystals or phenocrysts are imbedded. It may be glassy or vitrophyric, microfelsitic, hypocrystalline or holo-crystalline.

GYPSEOUS.—Containing gypsum or calcium-sulphate in appreciable quantity, in the form of crystals, strings, nodules or layers.

HACKLY.—A fracture exhibiting a rough, jagged surface, due to the granular-crystalline structure of the broken material, as in the native metals.

HALOED.—Surrounded by a deeply-coloured, pleochroic border, as in minute inclusions of apatite and zircon in biotite.

HARDNESS.—A physical property of much value in the preliminary determination of minerals, which depends upon the degree of cohesion of the particles. It is tested by scratching. Hardness is found to vary slightly in the same mineral, with the crystalline faces operated upon, and with the direction in which they

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are scratched. The scale of hardness, now in general use, was given by MOHS as follows: 1. The common foliated variety of *talc*; 2. *Rock-salt* or *gypsum*; 3. The transparent variety of *calc-spar*; 4. The crystalline variety of *fluor-spar*; 5. The transparent crystalline variety of *apatite*; 6. The cleavable variety of *orthoclase felspar*; 7. The transparent variety of *quartz*; 8. Transparent crystal of *topaz*; 9. Cleavable variety of *sapphire* or *corundum*; 10. *Diamond.*

HEATHEN.—A term used by quarrymen for the dark ovoid patches or "basic secretions" in granites. In Scotland any kind of dark blue-black rock in granitic districts is commonly called *heathen*, presumably on account of its colour, or because the occasional black boulders among the lighter prevalent granites are regarded as strangers, *ergo* heathen. Another explanation is that these dark rocks are prone to lose their corners by weathering, and masons cannot use them till they are "converted."

HEMICLASTIC.—When the grains of a clastic rock are joined together by a secondary cement, as in many quartzites.

HEMICRYSTALLINE.—A structure intermediate between the hyaline and holocrystalline, in which the matrix appears compact and even vitreous to the naked eye, but when examined with a lens or under the microscope is found to consist of an admixture of cryptocrystalline and microcrystalline forms.

HEMIHEDRAL.—In crystallography, where only half the number of faces which occur in the corresponding holohedral form are represented, either by the development of only alternate faces or of alternate groups of faces.

HEMIMORPHIC.—When the principal axis of a crystal is polar. Exhibited by crystals, other than those of the regular system, which present faces of totally different forms at the opposite ends of an axis of symmetry, as in calamine or hemimorphite, in which the pyro-electric property can be readily demonstrated.

HEMITROPIC.—Formerly used as synonymous with *twinned*, as all twinned crystals were supposed to be obtained by *hemitropy*, or a rotation through 180°, about an axis called the twin-axis.

HERRING-BONE STRUCTURE.—When crystals of augite in sections showing a fine basal striation combined with twinning on the orthopinacoid the characteristic herring-bone structure is manifested, as in the gabbro of Carrock Fell, Cumberland.

HERRING-SHOAL STRUCTURE.—HEDDLE'S name for the marked schiller-structure shown by the hypersthene in the paulite-norite of Banff.

HEXAGONAL.—Synonymous with Rhombohedral and Monotrimetric. One of the six systems of crystallography. It is possessed of seven planes of symmetry. The forms are

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referred to four axes, three of which are equal and similar, and intersect each other at an angle of 60°; while the fourth or principal axis is unequal and dissimilar, and stands at right angles to the plane of the other three.

HOLLOW SPHERULITES. — Synonymous with Lithophyses or Chambered Spherulites.

HOLOCRYSTALLINE.—Completely crystalline, without any glassy, microfelsitic or interstitial matter.

HOLOHEDRAL.—Those forms of any crystallographic system which are possessed of the full number of faces appropriate to the complete symmetry of the system. Synonymous with Holosymmetric.

HOMŒOCRYSTALLINE.—A granitic structure in which the mineral constituents are represented in equal proportions.

HORNFELSED.—Converted by extreme metamorphism into hornstone (Ger. *hornfels*, Fr. *cornéenne*), where all spotted, banded or schistose structure is merged into a compact and finely-textured mass of quartz, micas, iron-ores, etc., characterised by the presence of andalusite, garnet, etc.

HOUR-GLASS STRUCTURE.—A peculiar form of zonary growth, most frequently seen in augite, but also sometimes in hornblende crystals. It is emphasised by the examination of sections cut parallel to the clinopinacoid, or orthopinacoid between crossed nicols, when four fields are revealed, the alternate ones of which display similar colours; the direction of maximum extinction in the alternate fields being the same but differing somewhat in different pairs. This gives rise to a figure strongly resembling an hour-glass. Of course, when cut perpendicular to the vertical axis, sections merely show zonary structure. This phenomenon is attributed to the formation of an hour-glass-shaped skeleton crystal, the median depression of which is subsequently filled by augitic material of a slightly different chemical composition, and which therefore extinguishes at a slightly different angle. A modification of this structure is also seen in the manganese-bearing chloritoid mineral *ottrelite*, which is developed by thermal metamorphism in the Cambrian slate of Ottré, Ardenne, in Belgium.

HYALINE.—Clear and transparent, like glass.

HYALOPILITIC. — ROSENBUSCH'S term for the *felted* variety of ground-mass, characteristic of many andesites. It consists of numerous minute felspar laths, with or without granules of augite intermixed, and a residuum of isotropic glass.

HYDRAULIC.—Applied to limestone which contains 10 per cent. or more of silica and a little alumina; so that when burnt it yields a lime, which, mixed with water forms a cement capable of "setting" or hardening under water.

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HYDRO-METAMORPHISM.—When rocks are altered under conditions of low temperature and low pressure.

HYPABYSSAL.—BRÖGGER'S now generally accepted group of rocks which are intermediate in consolidation, between Plutonic and Volcanic rocks. *See* Dyke-rocks, Gang-gesteine.

HYPIDIOMORPHIC.—ROSENBUSCH'S term to indicate that only a minor proportion of the crystals in a rock assume idiomorphic outlines, as typically exemplified by the plutonic or rocks of deep-seated origin.

HYPOCRYSTALLINE.—Composed of both crystalline and glassy or microfelsitic matter, as in the ground-mass of porphyritic basalts.

HYPOMETAMORPHIC.—Used by CALLAWAY for the reception of rocks which are transitional between the shales and slates on the one, and schists on the other hand.

IDDINGSITIC.—A peculiar change manifested by olivine, which results in the formation of brown pleochroic pseudomorphs of a mineral (*Iddingsite*) with a perfect cleavage and a strong resemblance to mica.

IDIOCHROMATIC.—Applied to minerals that are possessed of an essential colour, as in metals and many of their salts.

IDIOMORPHIC.—Possessed of crystal faces proper to the mineral to which they belong. Synonymous with Automorphic.

IGNEOUS.—Rocks formed by the consolidation of molten matter. Synonymous with Exotic, Ingenitic, Pyrogenic.

IMBRICATED.—Overlapping, like tiles on a roof, as when tridymite occurs in lavas.

IMPLICATION STRUCTURE.—ZIRKEL'S term to include pegmatitic, oolitic, spherulitic, and other forms of structure.

INCLUSIONS.—The majority of rock-forming minerals contain inclusions or endomorphs of gases, liquids, glasses, microlites and crystals of other minerals; while some rocks contain fragments of other rocks which they have caught up and enwrapped during their molten condition.

INDIGENOUS.—Synonymous with Aqueous.

INDURATED.—Many rocks are hardened by various agencies. As a result of contact with intrusive masses, sandstones may be converted into quartzites and clays, into flinty slates, jasper, etc.; while by the action of heated water the percentage of silica may be increased by simple deposition in the interstices of the rock, or by the replacement of some of its minerals by silica, which consequently indurates the stone.

INGENETIC.—Synonymous with Igneous.

INSET.—BLAKE'S proposed term for Phenocryst, because it corresponds with the German *Einsprengling*.

INTERBEDDED.—Among sedimentary rocks it simply signifies

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alternate stratification; but in the case of igneous rocks, interbedding becomes equivalent to *contemporaneous*, and points to its volcanic origin.

INTERCEPT.—The distance from the origin at which a face cuts a crystallographic axis.

INTERFERENCE-FIGURE.—The figure obtained when the section of a doubly-refractive crystal is examined in convergent polarised light. Synonymous with Axial-figure.

INTERFERENCE-TINTS.—When sections of doubly-refractive crystal are examined between crossed nicols, they extinguish or remain dark only when they are placed in certain definite positions. In any other position, their effect, in conjunction with the nicols, is to partially suppress the several components of white light in various degrees, and thus to give rise in the emergent beam to polarisation or interference-tints.

INTERLACED.—A form of structure met with in schistose rocks, in which lamellar or granular layers of mineral particles meet and interlock to produce a kind of network which encloses the eyes or lenticular portions of the rock.

INTERPENETRATION-TWIN.—When two crystals pass more or less completely through each other they constitute an interpenetration-twin; typically represented by the cruciform growths of the orthorhombic mineral, therefore called staurolite.

INTERSERTAL.—Where a hypocrystalline or glassy ground-mass occurs as angular patches wedged in the interspaces of the phenocrysts and felspar laths, as in many andesites and basalts.

INTRATELLURIC.—That period in the consolidation of an igneous rock which precedes its eruption. Minerals which crystallise prior to the pouring out of the lava.

INTRUSIVE.—Igneous rocks which have been injected or forced through other rocks, but have not overflowed at the surface of the earth.

ISOMEROUS.—When the grains forming a rock are all approximately of equal size.

ISOTROPIC.—Singly refractive, and similar in optical properties to glassy and colloid substances. All crystals of the regular system are isotropic, and therefore give no reactions with polarised light.

JOINTS.—The divisional planes, other than those of bedding, cleavage or schistosity, which traverse both igneous and sedimentary rocks. DAUBRÉE groups all kinds of joints due to rupture of original continuity together as *Lithoclases*. To minor fractures he gave the name *Leptoclases*, which are

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subdivided into *synclases* or joints due to contraction on cooling or drying, and *piësoclases*, produced by external mechanical movement, notably pressure, which gives rise to the structures known as cone-in-cone, stylolites, and ruin-marble. Ordinary joints he called *Diaclases*, and faults, *Paraclases*.

JUXTAPOSITION-TWIN.—When two crystals are joined side by side, as frequently happens with the mineral gypsum.

KAOLINISATION.—The alteration of felspars by atmospheric and sometimes by solfartaric influences, to produce kaolin, a hydrated silicate of alumina. Under the microscope crystals of felspar undergoing this change become turbid or even opaque by the formation of minute scales and granules and diminutive monoclinic crystals of *kaolinite*.

KELYPHITIC.—*See* Celyphitic.

KNOTTED.—In the metamorphism of argillaceous rocks the type known as "spotted slate" (German, *Knotenschiefer*) exhibits little dark spots, knots, or concretions, which are sometimes found to consist of incipient crystals of andalusite, chiastolite, etc., but these disappear with advancing metamorphism.

LACCOLITE.—GILBERT'S generally accepted term to designate large masses of rock, which when molten have risen towards, but being unable to penetrate through, the surface, have spread out laterally and raised the strata above, so as to give rise to a dome-shaped structure.

LACUSTRINE.—Rocks formed by deposition in lakes.

LAMELLA.—A thin plate, such as the lamellæ in calcite and plagioclase felspars.

LAMINA.—Laminæ are the thinnest layers in the plane of deposit of a stratified rock. Lamination is well exemplified in shales.

LAPILLI.—Small fragments of lava, usually porous or minutely vesicular, that have been ejected along with ashes from volcanic vents.

LATERISATION.—In some tropical countries (Seychelle Islands) many igneous rocks, such as granite, gneiss, diorite and basalt, are broken down by subaerial decomposition into a cellular, reddish, ferruginous clay, which after being quarried dries into a very hard mass called Laterite.

LATTICE STRUCTURE.—The alteration of hornblende into serpentine, which proceeds along the cleavage-cracks intersecting at an angle of about 124°, gives rise to a lozenged-shaped or lattice-like structure.

LAVA.—Rocks produced by the consolidation of molten volcanic matter.

LENTICLES.—Minute lens-shaped structures often met with in

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minerals undergoing alteration and rocks subjected to mechanical metamorphism.

LEPTOCLASES.—*See* Joints.

LEPTOMORPH.—GÜMBEL'S term for a body which, although crystalline, is not bounded by crystallographic faces.

LIBELLA.—The bubble of gas contained in the liquid or glass inclusions of crystals.

LINEAR-PARALLEL STRUCTURE.—When the mineral particles in a rock are elongated and lie in one direction. This may arise from fluxion or be due to the crushing of the rock.

LITHOCLASES.—*See* Joints.

LITHOGENY.—The study of the origin of rocks.

LITHOID.—Like stone. Frequently used to signify that a glass has undergone devitrification.

LITHOLOGY.—The study of stones in the laboratory rather than out of doors.

LITHOPHYSES.—Originally applied to concentrically developed shrinkage-cavities in spherulites by VON RICHTHOFEN, but extended by IDDINGS to include all forms of hollowed spherulites. Some of these lithophysial chambers are lined with curious crystals of fayalite, tridymite, garnet, topaz, etc.

LITTORAL.—To indicate rocks that have been formed on the sea-shore.

LONGULITE.—Elongated cylindrical, elliptical or conical crystallites, sometimes with clubbed ends. They probably represent the complete union of a linear series of globulites (margarite) and frequently assume an arrangement parallel to the direction of flow.

LUSTRE.—A physical property of minerals, determined by the nature of their fractured surfaces with reference to the reflection of light. There are many kinds of lustre, the names of which are more or less self-explanatory, such as: *metallic*, *vitreous*, *resinous*, *pearly*, *silky*, *greasy* and *adamantine*.

LUSTRE-MOTTLING.—The interrupted sheen on the cleavage faces of minerals which enclose a fair number of endomorphs, as in the large ophitic plates of augite in many diabases, and the pœcilitic structure of many peridotites.

MACLED.—Twinned crystals usually betray their nature by the presence of re-entrant angles, which are manifested by jagged, notched, cordate, sagittate and knee-shaped forms. Hence the terms *geniculated* and *macled* are used as synonyms for twinned; while the French name *macle* is often substituted for twin.

MACROCLASTIC.—NAUMANN'S name for fragmentary rocks which are formed of large-sized clastic grains or pieces.

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MACRODIAGONAL.—The longer of the two lateral axes in the orthorhombic and triclinic systems of crystallography.

MACROPINACOID. — One of the three principal planes in the orthorhombic and triclinic systems, which lies parallel to the vertical axis and the longer of the two lateral axes.

MACROSCOPIC.—Visible to the naked eye. Synonymous with Megascopic in contradistinction to Microscopic.

MACULATED.—Synonymous with Spotted.

MAGMA.—The molten matter, which upon solidification becomes a rock-mass.

MAGMATIC.—Applied to ores which are differentiated from the magma injected into the crust of the earth.

MARGARITE.—Crystallites in the form of a string of pearls, formed by the coalescence of a linear series of globulites.

MARMAROSIS.—GEIKIE'S name for the conversion of ordinary limestones into crystalline marbles.

MASSIVE.—Uniform in structure in contradistinction to bedded or stratified. Igneous rocks in general are described as *massive*.

MATRIX.—The ground-mass in igneous, and the interstitial cement in sedimentary, rocks.

MECHANICAL METAMORPHISM.—*See* Dynamic metamorphism.

MEGASCOPIC.—Synonymous with Macroscopic.

MEROHEDRISM.—In crystallography includes Hemihedrism and Tetartohedrism.

MESH STRUCTURE.—The irregular netted structure characteristic of serpentine derived from olivine.

MESOSTASIS.—The interstitial matter found in hypocrystalline rocks, which may assume a vitreous, microfelsitic or cryptocrystalline character.

METACRASIS. — BONNEY'S term for the metamorphic change exemplified by the conversion of a mud into a mixture of quartz, mica and other silicates.

METAMORPHISM. — The structural, chemical or mineralogical changes which rocks undergo through thermal or mechanical agencies.

METAPEPSIS.—KINAHAN'S term to indicate metamorphism in rocks induced by intensely heated water or steam.

METASOMATIC.—The alteration in rocks due to chemical reactions, such as dolomitisation, silicification and phosphatisation.

METASTASIS. — BONNEY'S term for changes of a paramorphic character, such as marmarosis, devitrification, etc.

MIAROLITIC.—A drusy structure on a small scale, sometimes developed in granitoid and micrographic rocks, as in the "Diamond Rocks" of the Mourne Mountains in Ireland.

MICROCLASTIC.—Clastic rocks of very fine texture, in which the grains are of microscopic dimensions.

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MICROCLINIC.—A structure typified by sections of microcline when examined in polarised light under the microscope. It consists of a cross-hatched appearance, caused by simultaneous twinning on the albite and pericline laws; the lamellæ, however, are more or less tapering or spindle-shaped.

MICROFELSITIC.—When the matrix of certain hypabyssal rocks assumes a granular, fibrous or scaly structure, which does not react on polarised light as a rule. Weak double refraction, however, may be observed in microfelsitic textures when the particles are aggregated in parallel or radial masses.

MICROFLUXIONAL.—Fluxion or fluidal structure on a microscopic scale, as in many of the andesites.

MICROGRANITIC.—Rocks or the ground-mass of rocks, which show a minutely holocrystalline structure, composed of allotriomorphic granules, as in quartz-porphyries and eurites.

MICROGRANULITIC.—*See* Granulitic. The term has also been applied by JUDD to denote the characteristic structure of all true extruded lavas, especially of the basalts, where the augite of the ground-mass forms minute granules packed between the felspar laths.

MICROLITES.—This term is generally restricted to those minute crystalline bodies which react on polarised light, and can therefore be referred to the mineral species to which they belong.

MICROPEGMATITIC. — Pegmatitic structure on a microscopic scale. It is characteristic of the hypabyssal rocks known as granophyres.

MICROPERTHITIC.—Perthitic structure on a microscopic scale. BECKE'S term for the so-called striated orthoclase which, under the microscope, is resolved into an intimate intergrowth of orthoclase and plagioclase (oligoclase or albite). Thin lamellæ of the triclinic felspar being intercalated along the orthopinacoidal or prismatic planes of the orthoclase.

MICROPLACITE.—SCHRAUFF'S term for tabular microlites.

MICROPŒCILITIC. — Where a perimorph contains numerous rounded endomorphs of microscopic size. Also spelt Mikropoikilitic.

MICROSPHERULITIC.—Spherulitic on a microscopic scale.

MIGRATION STRUCTURE.—When crystalline needles and granules are disposed in bands or zones around the larger constituents of certain diabase-tuffs, GÜMBEL attributes this pseudo-fluxion structure to the alteration of old and the development of new material, thereby constituting a *migration* of mineral particles.

MIMETIC.—When a crystal imitates the symmetry of a higher system it gives rise to mimetic twins, and the crystals so twinned are said to be pseudo-symmetric, as in aragonite triplets.

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MOIRÉ.—The wavy appearance resembling the so-called "watered" silk presented by thin plates of mica between crossed nicols.

MONOCLINIC.—Possessed of only one plane of symmetry, the forms of this system of crystallography are referred to three unequal and dissimilar axes. Of these the two lateral axes are at right angles to one another, but only one of them is at right angles to the principal axis, and is called the *orthodiagonal*; while the other, which is inclined to the principal axis, is called the *clinodiagonal*. Synonyms for this system are: Clinobasic, Clinorhombic, Monoclinohedral, Monosymmetric and Oblique.

MONOGENOUS.—Fragmental rocks, the clastic particles of which are entirely derived from one pre-existing rock.

MONOSOMATIC.—When crystals and their inclusions both belong to the same mineral species.

MORTER STRUCTURE.—The *Mörtelstructur* of TÖRNEBOHM. A variety of cataclastic structure exhibited by certain crushed gneisses, where the larger components of the rock—its grains of quartz and crystals of felspar—are surrounded and cemented together by a finely granular mortar derived by the grinding down of the crystals themselves.

MYLONITIC.—The final result of the crushing, grinding down and rolling out of rocks by cataclastic processes, in which all the original structures are obliterated, save for the presence of occasional uncrushed "eyes" or lenticular patches, furnishes examples of LAPWORTH'S *mylonite*.

NECK.—The remaining roots of an ordinary volcanic cone.

NEEDLES.—Acicular prisms of minerals in rock-sections.

NEGATIVE.—When the optic axis coincides with the direction of greatest elasticity the crystal is optic negative. Negative crystals are glass inclosures which assume definite crystallographic forms, which correspond as a rule with those of the crystals in which they are found.

NEOVOLCANIC.—Applied by Continental petrographers to volcanic rocks of Tertiary and Post-tertiary age.

NEPTUNIC.—Synonymous with Aqueous.

NETTED.—The structure characteristic of serpentines formed by the alteration of augite which proceeds along the cleavage-cracks of that mineral, which intersect at an angle of 87°, and thus gives rise to an arrangement resembling network.

NODULAR.—Containing nodules, or irregular aggregations of rock-forming material, with or without nuclei, as in flint and ironstone.

OBLIQUE EXTINCTION.—Inclined at certain angles to crystallographic axes, or the edges which correspond with them. In

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the monoclinic system oblique extinctions obtain in sections parallel to the clinopinacoids, or plane of symmetry. In the triclinic system all extinctions are oblique.

OCEANIC.—Deep-sea deposits.

OCELLAR.—Synonymous with Centric structure.

OCTAHEDRON.—The simplest form in the cubic system, possessed of eight equilateral-triangular faces, each of which cuts the three axes at unit distance.

OOLITIC.—Like fish-roe. A rock composed of small spheroidal concretions which usually show a concentric and less often, a radial structure.

OPACITE.—Opaque grains and scales of decomposition products found in many rocks, the true nature of which cannot be microscopically determined.

OPALESCENT.—A lustre like that of opal or mother-of-pearl, which exhibits a play of colours.

OPHITIC.—One of the characteristic forms of structure developed in diabases and deep-seated dolerites, where it consists of a plexus of felspar-laths as endomorphs in large plates or perimorphs of augite. Other minerals have been observed to be similarly intergrown, the one being slightly anterior to the other in its consolidation.

OPTIC AXIS.—The direction in anisotropic crystals along which a ray of light does not become doubly refracted. When there is only one such axis, as in the Tetragonal and Hexagonal systems, the crystals are called *uniaxial*, and the optic coincides with the principal crystallographic axis. When two such axes obtain, as in the Orthorhombic, Monoclinic and Triclinic systems, the crystals are called *biaxial*, and the position of the axes varies with the mineralogical and sometimes with the chemical composition, and may likewise be influenced by the temperature.

ORBICULAR.—When the component minerals of a rock have crystallised into spheroidal aggregates, as strikingly exemplified by the corsite, napoleonite or ball-diorite of Corsica, and in many granites and gabbros.

ORGANOGENIC.—Of organic origin. *See* Phytogenic and Zoogenic.

ORIENTATION.—The relative direction of the crystallographic axes, or of the axes of elasticity in two or more crystal sections under the microscope determines their orientation; so that similarly oriented sections extinguish simultaneously when revolved between crossed nicols.

OROGENETIC.—Mountain-forming rocks.

ORTHODIAGONAL.—*See* Monoclinic.

ORTHOGNEISSIC.—Pertaining to gneissic rocks, which can be traced to an igneous origin.

ORTHOPHYRIC.—ROSENBUSCH'S name to designate the character of

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the ground-mass in certain porphyries, porphyrites and trachytes, where the minute felspars are stout, short and untwinned, and generally referable to orthoclase.

ORTHOPINACOID.—One of the three principal crystallographic planes in the Monoclinic system. It lies parallel to the vertical and horizontal axes.

ORTHORHOMBIC.—One of the six crystallographic systems. It is possessed of three planes of symmetry, and its forms are referred to three unequal and dissimilar axes which remain at right angles to one another, and any one of which may be taken as the vertical axis. Synonymous with Rhombic, Prismatic, Anisometric and Trimetric.

OSCILLATORY.—The fine parallel striation which results when the faces of two different forms of the same order are developed in a crystal.

OUTCROP.—The edges of a stratum as it is revealed on the surface of the ground. Synonymous with Basset.

OUTLIER.—An eminence detached by erosion from masses of rock of which it once formed a part.

PALÆOVOLCANIC.—Volcanic rocks of pretertiary age.

PANIDIOMORPHIC.—ROSENBUSCH'S term for rocks in which all the mineral constituents are idiomorphic, as in many lamprophyres.

PANNIFORM.—When a consolidated lava presents a crumpled or corrugated appearance.

PARACLASE.—Synonym for Fault. *See* Joints.

PARAGENESIS. — BREITHAUPT'S term to explain the intimate association of minerals and the laws which control those phenomena.

PARALLEL STRUCTURE.—The structure in rocks exemplified by the arrangement of its mineral particles or differently constituted parts into more or less parallel bands, as in lamination, fluxional structure and schistosity.

PARAMETERS.—The ratios of the intercepts of a crystal.

PARAMORPHIC.—STEIN'S name for those changes which give rise to pseudomorphs without a loss or gain of mineral matter. Synonymous with Allomorphic.

PAROPTESIS.—KINAHAN'S term for Contact-metamorphism.

PARTING.—A thin layer of some soft rock between two beds of harder material. In microscopic petrography a parting designates the kind of lamellar separation seen in diallage.

PEG STRUCTURE.—The *Pflockstructur* of STELZNER, as seen in sections of melilite under fairly high powers of the microscope. The cross-fibration of the lath-shaped sections are often modified by peculiarly-shaped pegs, spears, or spatulæ, which project from the basal planes towards the centre of the crystal.

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PEGMATITIC.—The structure produced by the intimate intergrowth of two minerals, such as quartz and felspar in pegmatite.

PELITIC.—Pertaining to mud or fine argillaceous sediment derived from the waste of rocks.

PERIMORPH.—When one mineral incloses another or several others it is called a *perimorph*, while the inclusions are termed *endomorphs*.

PERLITIC.—Curvilinear cracks developed by the contraction of the homogeneous material of glassy or rhyolitic rocks. The curved and sometimes straight cracks form parts of the boundaries of spheroidal, ellipsoidal and subcylindrical separations, which give rise to the structure characteristic of the perlites.

PERTHITIC.—A structure typified by perthite, which consists of, and intergrowth of, monoclinic and triclinic felspars. *See* Microperthitic.

PETROGENY.—The science of the formation of rocks.

PETROGRAPHY.—Those parts of the study of rocks concerned with their mineralogical and microscopical characteristics.

PETROLOGY.—The science of rocks in all its branches.

PETROSILEX.—The French name for the cryptocrystalline ground-mass of many of the acid-intrusive rocks, which chemical analysis indicates to be an amalgamation of quartz and felspar.

PFLOCKSTRUCTUR.—*See* Peg structure.

PHANEROCRYSTALLINE.—In contradistinction to *cryptocrystalline* is sometimes applied to all manifestly crystalline structures when viewed either by the naked eye or under the microscope with ordinary light.

PHANÉROGÈNE.—The French term for manifestly granular in contradistinction to *adélogène*.

PHANEROMEROUS.—Rocks composed of comparatively coarse grains or particles in contradistinction to *cryptomerous*.

PHASE.—To denote the stages or periods of crystallisation in the consolidation of a rock.

PHENOCRYSTS.—A term introduced by IDDINGS to denote the porphyritic crystals which are more or less idiomorphic and stud the ground-mass of many igneous rocks. Synonymous with Inset and *Einsprengling*.

PHOSPHATISATION.—A metasomatic change met with in some calcareous rocks, where the carbonate of lime is partially or wholly replaced by phosphate of lime.

PHYTOGENIC.—Rocks mainly derived from plant remains, such as coal, lithothamnion-limestone, etc.

PIËSOCLASES.—*See* Joints.

PIESOCRYSTALLISATION.—A term introduced by WIENSCHENK to denote: "An entirely primary formation of massive rocks, wherein, besides the high tension allowed for the crystallisation

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of a normal deep-seated mass, there must also be reckoned the compression due to orographic movements during the consolidation of the rock."

PILOTAXITIC.—ROSENBUSCH'S name to indicate the nature of the ground-mass in certain porphyries and andesites, where it consists mainly of minute laths of plagioclase felspar, frequently exhibiting fluxional phenomena, but without any interstitial glass. *See* Hyalopilitic.

PISOLITIC.—When the oolitic grains in a rock are at least as large as peas, as in the Colwall Copse limestone of the Malvern Hills.

PLASTIC.—Capable of being moulded or used for modelling, like moist clay or "plaster of Paris."

PLEOCHROIC.—The property possessed by transparent doubly-refractive crystals of giving different absorption-tints for different directions of vibration of the light within the crystal. Uniaxial minerals are called *dichroic*, because they possess two directions in which the greatest difference of colour is shown; whereas biaxial minerals are said to be *trichroic*, by reason of the three directions along which rays of different intensity are transmitted, to correspond with their three different axes of elasticity. Pleochroism is a useful adjunct in the determination of minerals under the microscope. To employ it for this purpose only the lower nicol should be used, and either it or the stage carrying the object may be rotated. The direction of vibration is that of the shorter diagonal of the polarising prism.

PLUTONIC.—Rocks of deep-seated consolidation, which bear evidences of very gradual cooling under enormous pressure. Synonymous with Abyssal and Hypogenic.

PLUTONIC ACTION.—Called *hypogene*, with reference to changes caused by the original internal heat and chemical reactions within the earth.

PNEUMATOLYTIC.—The emanations and sublimations associated with the rising of molten matter, and which have been shown to be materially instrumental in the crystallisation and differentiation of igneous rocks, were called *mineralising agents* by ÉLIE DE BEAUMONT, and classed together as *pneumatolytic*, a term which BRÖGGER has extended to include the minerals produced by those agents, whether they remain in the rock itself or pass into fissures or crevices in the surrounding rocks.

PŒCILITIC.—Analogous to the ophitic structure of the diabases and some dolerites, this structure is typically exemplified by the picrites, where large perimorphs of either augite or hornblende are liberally studded with endomorphs of more or less rounded crystals of olivine, giving to the fractured surface of

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many of these rocks their characteristic lustre-mottling. Also spelt Poikilitic and Poicilitic.

POLARISATION-TINTS.—*See* Interference-tints.

POLYGENOUS.—Clastic rocks, the fragments of which are derived from two or more differing rocks.

POLYMORPHIC.—Capable of consolidating into two or more forms of molecular structure. When crystalline this difference is expressed in the different parametral values of the axes of the various crystal-forms. Crystals may be *dimorphic*, as in carbonate of lime, which occurs as calcite and aragonite in the hexagonal and orthorhombic systems respectively; *trimorphic*, as in titanic acid, which takes the forms of rutile, anatase and brookite, etc. Synonymous with Pleomorphous.

POLYSYNTHETIC.—Repeated twinning in lamellæ, giving rise to a striated structure, which is emphasised when examined in polarised light; as well exemplified by the triclinic felspars.

PORODINE.—BREITHAUPT'S term for amorphous matter which has consolidated slowly from a colloid condition, as in the case of opal.

PORPHYRITIC.—When a rock of igneous origin is clearly composed of a ground-mass studded with larger crystals, thereby indicating an earlier and later stage in its consolidation. The large crystals of the first crop are called *porphyritic*. The structure is best developed in volcanic, less in hypabyssal, and is practically unrepresented in true plutonic rocks.

PRESSURE METAMORPHISM.—*See* Dynamic metamorphism.

PRISM.—This crystallographic form results as the combination of a plane of symmetry with a centre of symmetry. A prism face cuts two axes, but is situated at infinity to the third. Prisms are open forms, and are called vertical, transverse or longitudinal according to the axis to which their edges are parallel.

PRISMATIC.—Minerals are so called which occur in acicular or columnar forms, and give lath-shaped sections; while in rocks the term is applied to that mode of jointing commonly called columnar.

PROPYLITISATION.—The characteristic alteration undergone by certain volcanic rocks of the andesitic type, whereby the ferro-magnesian constituents are chloritised and the felspars converted into epidote, has been ascribed to solfataric action, *i.e.*, the influence of hot vapours and gases.

PROTOGENIC.—Sometimes applied to crystalline rocks of igneous origin, in contradistinction to derived or *deuterogenic* rocks.

PROVINCE.—In petrography is applied to any area characterised by the prevailing occurrence of a particular type of rocks.

PSAMMITIC.—Composed like sandstone of small, more or less rounded grains.

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PSEUDOMORPHOUS.—Applied to minerals which have by replacing other minerals assumed the external forms of the latter.

PSEUDOPORPHYRITIC.—HARKER'S term for large crystals found studding certain of the most basic peridotites, but have not originated as the first crop of two generations of the same mineral in the rock.

PSEUDOSPHERULITIC.—ROSENBUSCH'S term for the spheroidal crystalline aggregates exhibiting radial structure which are found in acid igneous rocks; notably clustered round porphyritic crystals of quartz or felspar, or as numerous closely apposed spherules in acid rocks of granophyric type.

PSEUDOSTROMATISM. — BONNEY'S term to indicate the false-bedding parallel to cleavage foliation which is sometimes developed in crystalline rocks by pressure.

PUMICEOUS.—Like pumice-stone, where the cellular structure is so largely developed that the rock would almost float on water.

PYRAMID.—A solid bounded by faces which meet in a point on either side of a plane or basis, the form of which depends upon the system to which the crystal belongs. A pyramid face cuts three axes, and pyramids are closed forms.

PYRITOUS.—Rocks which hold diffused disulphide of iron.

PYROCLASTIC. — Fragmental rocks of igneous origin, such as volcanic ashes, tuffs, agglomerates, etc.

PYROGENIC.—Produced by igneous agency. Sometimes used as synonymous with Igneous.

PYROMERIDE.—The aggregated nodular bodies found in many ancient rhyolites, originally formed by devitrification, and subsequently more or less altered by the deposition of secondary quartz and chalcedony in them.

QUADRATIC.—Sometimes used for Tetragonal in crystallography.

QUARTZ AURÉOLÉ.—A French designation for quartz crystals in certain felsophyric porphyries, enveloped by a slightly clouded zone, which, between crossed nicols, extinguishes simultaneously with the central core. Its turbidity is due to the presence of a trifle of felspar or microfelsite, which becomes kaolinised.

QUARTZ DE CORROSION.—LACROIX'S name for the crowds of little rounded or elongated inclusions of quartz found in the felspars of charnockites (South Indian hyperthene-granites) which are not so regularly developed as to produce a graphic intergrowth. This is attributed to secondary corrosion.

QUARTZ SILLIMANITISÉ.—Matted masses of fibrolite or sillimanite needles found in the quartz of certain argillaceous rocks that have undergone thermal metamorphism.

QUARTZOSE.—Containing abundant quartz.

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RADIO-ACTIVITY.—Elements of high atomic weight are believed to be slowly changing into elements of low atomic weight. By the disintegration of their molecules, not only is heat evolved, but a peculiar emanation which constitutes the radio-activity of the element, and is probably the source of three distinct kinds of rays, which react in different ways upon their surroundings—ionizing gases and rendering certain minerals luminescent. In the case of radium, the emanation after a time becomes changed into helium, which is another element, but of low atomic weight. Among the most important of radio-active elements yet discovered are: Radium, Uranium, Thorium, Polonium, Actinium, Berzelium, Carolinium, and an element resembling Lead.

RAPILLI.—Synonymous with Lapilli.

REACTION-RIMS. — The borders sometimes developed at the junction of two different minerals in a crystalline rock.

REFLECTION PHENOMENA.—The surfaces of opaque minerals, and especially of metals and metallic-ores, often reveal characteristic traces of structure, which are of service in determinations under the microscope, when examined under reflected light.

REFRACTIVE INDEX.—The aspect of minerals in rock sections under the microscope, and especially of inclusions in minerals, varies greatly according to their mean refractive indices. It is therefore of importance to become familiar with the effects due to a high or a low refractive index.

REGULAR.—The system of crystallography characterised by nine planes of symmetry. It is possessed of three equal and similar axes, standing at right angles to one another, any of which may therefore be taken as the principal axis. Synonymous with Cubic, Octahedral, Tesseral, Tessular, Isometric and Monometric.

RETICULATED.—Having a netted, latticed, cellular, or anastomosing structure.

RHOMBIC.—*See* Orthorhombic.

RHOMBOHEDRAL.—*See* Hexagonal.

ROCK.—A mass of matter composed of one or more minerals, whether compact or incoherent, but possessed of a more or less uniformly persistent character. Thus, granites, basalts, sandstones, limestones, clays, peat and even blown-sand, may all be called rocks; but mineral veins, veinstones and ore, etc., do not come within the meaning of the term as they are usually variable both with regard to structure and substance.

ROCK-FLOUR.—*See* Till.

SACCHAROID.—In texture resembling loaf-sugar, where minute interspaces occur between the approximately uniform-sized differently-orientated crystalline grains; as in statuary marble.

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SALBAND.—A German term to indicate a thin crust at the margin of a vein or dyke.

SAUSSURITISATION.—A mineralogical transformation, following upon pressure, whereby the soda-lime felspars are altered into a minutely granular aggregate of variable character called *saussurite*. The soda-bearing silicate separates out into very minute, clear, glassy crystals of albite; while the lime-bearing silicate combining with other constituents of the rock, yields small prisms of zoisite, or faint yellow to colourless epidote, which may be accompanied by greenish fibrous hornblende or actinolite needles.

SCALE.—A diminutive lamina, frequently met with in rocks, especially those that are undergoing alteration, *e.g.*, scales of paragonite, kaolin and chlorite.

SCAPOLITISATION.—When sodium chloride is present in solution during the dynamic metamorphism of rocks, a complete change ensues, whereby plagioclase felspar becomes altered into scapolite.

SCHILLERISATION.—JUDD'S name for the change induced in the minerals of deep-seated rocks, whereby crystals of tabular, bacillar, or stellar habit are developed along certain planes, the "schiller-planes," which give rise to the peculiar sub-metallic lustre called *schiller*, so well shown by some minerals, such as bronzite and hypersthene, when held in suitable positions.

SCHISTOSITY.—The fissile structure characteristically developed in the crystalline schists, as the result of mechanical metamorphism.

SCORIACEOUS.—A variety of the cellular structure of volcanic ejectamenta, where the cells or vesicles of various shapes and sizes occupy about as much space as the solid portion, and present, like scoriæ, a cindery appearance.

SECONDARY.—Minerals which are derived from the alteration of the original constituents, but still form part of the rock structure.

SECRETION.—When a mineral grows from without inwards, as when cavities and fissures are filled by the deposition of materials on their walls; *e.g.*, mineral veins and amygdules.

SEDIMENTARY.—Stratified deposits mainly formed under water. *See* Aqueous.

SEGREGATION-VEINS.—Irregular bands of usually coarser texture found in intrusive sheets along certain lines or around special centres, probably produced by segregation from the surrounding rock.

SEMICRYSTALLINE.—Eruptive rocks composed of a mixture of crystalline and amorphous matter; or fragmental rocks in which there is a large proportion of crystalline cement.

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SEPTARIAN STRUCTURE.—Concretions of limestone and clay-ironstone during their consolidation frequently shrink and crack internally, and the shrinkage cavities thus developed generally radiate irregularly from the centre towards the boundaries which they all but reach. The spaces within are subsequently filled with infiltrated matter, notably calcite.

SEQUENCE OF CRYSTALLISATION.—The order in which the various minerals composing igneous rocks have crystallised out of the molten magma is, according to ROSENBUSCH, reducible to a law of "decreasing basicity."

SERICITISATION. — As a result of mechanical metamorphism, felspathic rocks undergo more or less radical changes. The interior of plagioclase crystals may be partially or wholly altered into scales of paragonite; while orthoclase similarly gives rise to muscovite. When the pressure is intense, colourless mica may be formed at the margin of a crystal or on surfaces of lamination or of movement in the felspathic rock, giving birth to the unctuous, silky mica called *sericite*; while extreme crushing may convert massive orthoclase rocks, such as granites, and also felspathic grits, into sericite schists. Synonymous with Micasisation.

SERPENTINISATION.—The conversion by secondary decomposition changes of the non-aluminous magnesian silicates—olivine, rhombic pyroxenes, and sundry augites and hornblendes—into the hydrous magnesian silicate, serpentine.

SHALY. — Consisting of finely laminated leaf-like strata, as characteristically exemplified by shales.

SHEARING.—Differential movement set up in a solid rock-mass. When such movement is concentrated along a plane, the latter is called a *shear-plane*.

SHEET.—A mass of igneous rock which lies spread out over a large area or has been intruded between bedded rocks so as to appear stratified.

SHIMMER-AGGREGATE. — The name given by BARROW to the masses of white micaceous scales resulting from the decomposition of aluminous silicates in rocks.

SIGMOIDAL.—By unequal progression of the different parts of slowly moving lava streams, internal folds are produced in form of the letter S. Such sigmoidal flexures are sometimes also developed in foliated rocks which have undergone mechanical metamorphism.

SILICIFICATION. — The introduction of silica from an external source to set up secondary alterations, as in certain rhyolites; to replace matter that has been removed, as in metasomatic changes in limestones; or by infiltration of colloid silica to form opal.

SKELETON-CRYSTALS.—During rapid crystallisation many minerals

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solidify into incipient or abortive forms, which assume curious forked and incomplete framelike shapes, as frequently met with in triclinic felspars and minute crystals of olivine and hornblende.

SLATY.—Resembling the cleavage-structure of slates.

SLICKENSIDES.—The smoothened and often grooved surfaces of rocks due to the friction of the faces of a fault or joint during the displacement.

SOLFATARIC ALTERATIONS.—The changes incident to surrounding rocks subjected to the volatile emanations from volcanoes that are waning in their activity.

SOLUTION-PLANES.—The planes in a crystal along which it most easily succumbs to chemical reactions. These planes are parallel to one or more crystallographic planes; but when a secondary lamellar twinning is set up by strain in a crystal, the gliding-planes become the easiest solution-planes.

SPECIFIC GRAVITY.—The weight of a body compared with that of an equal volume of distilled water at a temperature of 60° F. Is of advantage in discriminating between rocks.

SPHERIC STRUCTURE.—Constituted by the arrangement of the particles of a rock around certain centres to produce concentric, radiate or granular spheroidal bodies, such as oolitic, variolitic, centric, spherulitic structures, as well as belonospherites, globospherites and granospherites.

SPHEROCRYSTAL.—Belonospherites constituted by only one kind of mineral disposed in radiating fibres or needles.

SPHEROIDS.—The globular-shaped concretionary bodies found in certain granites and diorites, such as the orbicular corsite.

SPHEROIDAL STRUCTURE.—When igneous rocks contract in such a way when cooling that they subsequently weather into ball-shaped masses possessed of a concentric structure.

SPHERULITIC.—This kind of structure, which commonly occurs in vitreous igneous rocks, consists of the aggregation of incipient crystals intergrown in such a way as to produce more or less globular bodies, which may range in size from microscopic dimensions to as much as 10 feet in diameter. Under the microscope the crystalline intergrowth may be resolved into straight or branched needles or fibres radiating from a centre, a nucleus, or a shrinkage cavity, and the *spherulites* thus formed consequently show a black cross in polarised light. A cessation of growth followed by subsequent secondary concentric developments may also sometimes be observed. Other very minute spherulites may be closely crowded together in bands or masses to constitute the *microspherulitic* structure, or when they coalesce in linear arrangement give origin to modified elongated forms called, by ZIRKEL, *axiolites*.

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Again, larger spherulites may consist merely of skeleton-crystals imbedded in a glassy or devitrified matrix, and are described by COLE as *skeleton spherulites*. Then there are curious globular aggregations of minerals not simultaneously but successively intergrown to reproduce the ophitic or pœcilitic structure on a minute scale, to which WILLIAMS has given the name *micropœcilitic*. Lastly, when spherulitic structures have undergone changes, either during or subsequent to their formation, lithophysæ and the curious spherulitic rhyolites of the Wrekin and the pyromerides of Wuenheim, with secondary quartz and chalcedony in them, obtain.

SPICULAR.—Minerals which occur in small dart-shaped forms. Rocks more or less composed of the spicules of organisms, as in cherty sponge-rock, etc.

STELLATE.—Star-shaped or radiating from a centre, as in some fibrous minerals, such as actinolite.

STRAIGHT EXTINCTION.—Among anisotropic crystals parallel or straight extinctions are those in which the directions of maximum extinction are parallel to those crystallographic edges which correspond with certain crystallographic axes. Thus, in the orthorhombic system straight extinctions occur in sections parallel to the macropinacoids, brachypinacoids, and basal planes. In the tetragonal and hexagonal systems they take place in sections parallel to the principal crystallographic axis; and in the monoclinic system in sections that are parallel to the orthopinacoids and basal planes. For example, when the nicols are crossed, a longitudinal section of apatite, which belongs to the hexagonal system, will extinguish when its length (optic axis) is parallel to either of the diagonals of the nicols.

STRAIN-SHADOWS.—The effects of strain are frequently manifested by a modification of the optical properties of crystals in a rock-mass. These become apparent by the examination of sections between crossed nicols. Upon revolution of the section, instead of remaining uniformly dark in certain definite positions, the crystal behaves anomalously by showing dark shadows which shift across it as the section is rotated, by reason of the variation in the directions of extinction from point to point.

STRAIN-SLIP-CLEAVAGE.—*See* Close-joints-cleavage and Ausweichungsclivage.

STRATIFIED FOLIATION.—Where the foliation of the minerals lies parallel to the stratification of the rock.

STRATUM.—A layer of rock deposited by aqueous agency.

STRIATED.—Exhibiting a parallel finely-striped structure, as in the plagioclase-felspars; or superficially scored, as in ice-worn rocks.

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STRIKE.—The direction of a stratified bed indicated by the line formed by the intersection of the plane of the bed with the plane of the horizon, and recorded by reference to the points of the compass.

STYLOLITES.—Curious cylindrical or columnar bodies, up to about 4 inches in length, with longitudinally striated or grooved sides, and usually capped with clay, which are found in certain limestones, dolomites and marls, placed vertically to the bedding of the rock, of which they are modifications due to pressure.

SUBAERIAL.—Rocks formed or changed at the surface of the earth.

SUBAQUEOUS.—Rocks deposited under water.

SUBLIMATION.—Products formed by vaporisation and condensation.

SUBSEQUENT.—Sometimes employed to signify *intrusive* rocks.

SYNCHRONOUS.—Belonging to the same age or period.

SYNCLASES.—*See* Joints.

SYNCLINAL.—Strata which dip towards a central axis, in contradistinction to Anticlinal.

SYSTEM.—At the International Geological Congress held at Bologna in 1881 stratified rocks were classified as follows: *Strata* unite to form an *assise*; assises to form a *stage*; stages to form a *series*; series to form a *system*; and systems to form a *group*.

TABULAR.—The bedded structure sometimes found in many igneous rocks, produced by horizontal jointing and emphasised by weathering.

TALCOSE.—Bearing a large proportion of talc.

TAUTOZONAL.—Those faces of crystals which lie in one and the same zone.

TAXITIC.—LOEWINSON-LESSING'S name to indicate an arrangement in volcanic rocks in the crystallisation of which two products result, each distinct from the other in colour, structure and composition. Taxitic rocks thus appear to be of clastic, although they are in reality of primitive origin. Such are the eutaxites of the Canary Islands and the piperno of Pianura, near Naples.

TETARTOHEDRAL.—Crystals which present only a quarter of the full number of faces.

TETRAGONAL.—The system of crystallography characterised by five planes of symmetry. Its forms are referred to three axes standing at right angles to one another, two of which are equal and similar; while the other, which is the chief axis, is unequal and dissimilar. Synonymous with Dimetric, Monodimetric, Quadratic, Pyramidal and Prismatic.

TETRAHEDRON.—The hemihedral form derived from the regular octahedron by the extirpation of its alternate faces.

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TEXTURE.—Formerly applied to the size and mutual relations of the constituents in rocks to distinguish it from *structure*, which was restricted to defining the nature of the form assumed by the rock upon its consolidation.

THALASSIC.—Sedimentary rocks that have been deposited at the bottom of the smaller seas, in contradistinction to Oceanic.

THERMAL METAMORPHISM.—All the changes produced in rock-masses by the agency of heat. These are due: (α). To the intrusion of an igneous magma which alters the rocks in its neighbourhood (contact-metamorphism). (β). To the effects of heat mechanically produced. (γ). To the internal heat of the Earth in a rise of the isogeotherms, and may therefore give rise to metamorphism in rocks throughout a large area (regional-metamorphism).

THREAD-LACE SCORIA.—The name applied to the rare pumiceous variety of volcanic slags, such as the basalt-glass which forms a crust of about 2 inches in thickness of a scoriaceous nature upon the lavas of Hawaii, and the curious filaments of clear volcanic glass which lie thickly matted like mown grass and are known to the Sandwich islanders under the name of "Pélé's Hair."

THRUST-PLANE.—A reversed fault which lies but slightly inclined to the horizon.

TILL.—Microscopical examination of the Glacial tills shows that a large part of even the most impalpable material is of detrital origin, which is of the nature of what CROSBY calls *rock-flour*, and consists of excessively fine pulverised quartz and other rock-forming minerals which, unlike clay, have not undergone chemical decomposition.

TRACHYTIC.—Applied to the characteristic structure of the ground-mass in the trachytes. It consists essentially of a plexus of minute felspar crystals or microlites of lath-shaped habit, showing some degree of parallel disposition due to fluxion. The trachytic structure may also sometimes be met with among nepheline-syenites.

TRAPPEAN.—A loosely-applied term for igneous rocks which often occur lying in the form of steps or terraces; it has been retained by GEIKIE to indicate true volcanic rocks irrespective of the geological formations to which they belong.

TRICHITES.—ZIRKEL'S name for the crystallites of curved hair-like form found in vitreous matter. Under high powers of the microscope these minute bodies may sometimes show a beaded structure, and often give evidences of having been formed subsequent to the flowing movement in the molten mass. Trichites frequently form groups radiating from a common centre or nucleus.

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TRICHROIC.—*See* Pleochroic.

TRICLINIC.—The system of crystallography devoid of any plane of symmetry. The forms are referred to three unequal and dissimilar axes which all cut one another obliquely. Synonymous with Asymmetric, Anorthic, Doubly Oblique and Triclinohedral.

TRIMORPHIC.—*See* Polymorphic.

TUFACEOUS.—Of the nature of travertine or calcareous tufa, stalactites and stalagmites.

TUFFACEOUS. — Bearing more or less volcanic ejectamenta deposited along with other materials, as in *tuffaceous* shales, limestones, sandstones, etc.

TWINNING.—MIERS notes that: "When two or more crystals are so united that one is symmetrical to the other about a plane which is a possible face on each, or about an axis which is a possible edge on each, the crystals so united are said to be *twinned*; the plane of symmetry is called the *twin plane*, and the axis of symmetry is called the *twin axis*. . . . It was formerly the custom to describe all twins as obtained by *hemitropy*, or rotation through 180°, about an axis which is called the twin axis, whether a possible edge or not, and to call the plane perpendicular thereto the twin plane, whether it be a possible face or not. Since, however, a right and a left-handed crystal of quartz are sometimes twinned together so that they are symmetrical about a plane parallel to one of their faces, and yet, the one cannot be obtained from the other by a rotation, any more than a right-hand glove can be placed parallel to a left-hand glove, it is clearly impossible to describe all twins as due to hemitropy." Under the microscope the existence of twinning in a section of crystal is instantly revealed between crossed nicols, since the two individuals of the twin extinguish, as a rule, in different positions, and exhibit different interference-tints. This, of course, does not apply to crystals like the spinels, which are optically isotropic or opaque, nor to those cases, as seen in quartz, in which the law of twinning is such that the axes of optic elasticity remain unchanged. When the extinction angles are equal but in opposite directions, it shows that the crystal has been cut approximately in a direction perpendicular to the twin plane; but if the direction of the section is at a small angle with the twin plane, the individuals will be seen to overlap appreciably and give rise to an intermediate narrow band which does not behave in optical unison with either side. In the case of polysynthetic twinning, as characteristically seen in triclinic felspars, the lamellæ are seen to extinguish alternately into two sets.

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UNCONFORMABILITY. — In contradistinction to *Conformable.* Where there is a distinct stratigraphical break between two sets of beds, with regard to both dip and strike. This may arise either by the denudation of the earlier strata, or by their upheaval and denudation prior to the deposition of the later beds.

UNDULOSE EXTINCTION.—The phenomenon of *strain-shadows*; seen when sections of crystals which have been subjected to mechanical forces are revolved between crossed nicols. This appearance has also been styled Spectral-polarisation.

UNIAXIAL. — Where there is only one optic axis, as in the forms of the hexagonal and tetragonal systems of crystallography. In all these cases the direction of the optic axis coincides with or is parallel to the principal crystallographic axis. In some uniaxial crystals the ordinary is less refracted than the extra-ordinary ray, and they are called positive; but when the converse happens and the ordinary ray is the more refracted the crystals are said to be negative.

URALITISATION. — The change typically exemplified by the mineral uralite which, exhibiting the faces of augite, is possessed of the cleavage of hornblende, and is in reality a pseudomorph of hornblende after augite. In all cases, however, uralitisation may not be a merely paramorphic change or molecular rearrangement, but appears often to involve special chemical reactions such as the higher oxidation of the iron and a loss of part of the lime of the augite, to contribute to the production of other alteration products such as epidote. Uralitisation is well exemplified in rocks which have undergone contact-metamorphism, such as the conversion of diabases into proterobases, where the crystals of augite may be seen in every stage of change passing into the condition of compact to fibrous hornblende.

VARIOLITIC.—The structure exemplified by certain basaltic glasses closely allied to the spherulitic tachylites and the altered marginal portions of diabasic and doleritic rocks. These are characterised by the development in them of more or less closely crowded *varioles* or spheroidal bodies, usually ranging from 0·10 to 0·5 inch, but sometimes attaining to the size of from 2 to 3 inches in diameter. In internal structure the varioles may show a mere fan-like or sheaf-like grouping of felspar microlites, or assume very regular and radiate spherulitic forms. Both varioles and the glassy matrix are very prone to alteration.

VEIN.—Any mass of mineral matter filling up a crack or fissure in rocks.

VESICULAR.—When a rock-magma has been distended by bubbles

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of steam, and consolidated into a cellular mass containing comparatively few and small cavities.

VIRIDITE.—Green decomposition products found in the majority of basic igneous rocks which do not admit of exact determination. They may be transparent, translucent, and in scaly or fibrous patches, and are probably of the nature of serpentine in some cases or of chlorite or delessite in others.

VITREOUS.—Synonymous with Glassy.

VITROPHYRIC.—Applied to the glassy type of porphyritic structure characteristic of the pitchstones among the acid-intrusive rocks and glassy volcanic rocks or parts of rocks, *e.g.*, rhyolites and tachylites.

VOLCANIC.—Rocks of volcanic origin, which have consolidated at or near the surface of the earth.

WEATHERING.—The result of all kinds of meteoric action upon rocks at the surface of the earth.

XENOCRYSTS.—The term introduced by SOLLAS to signify crystals that have been derived from some other rock, and are therefore foreign to the mass of igneous origin in which they occur.

XENOLITHS.—Stones that have been caught up and involved in the molten magma of erupted rocks.

XENOMORPHIC.—ROHRBACH'S term for Allotriomorphic.

YARPHIC.— Peaty; so-called from *yarpha*, the name for peaty soil in Shetland.

ZONE.—A group of faces parallel to one and the same straight line called the *zone-axis*. Such faces are called tautozonal; while a plane perpendicular to the zone-axis is termed the *zone-plane*. In stratigraphical geology the word zone is applied to a bed or series of beds characterised by one or more distinctive fossils. Also called Horizon.

ZONED.—The structure shown by minerals in which the growth of the crystals is indicated by bands or zones of inclusions, or a change in chemical composition. Sometimes one mineral is surrounded by a narrow band or zone of another mineral.

ZOOGENIC.—Essentially of animal origin as in chalk or coral-beds.

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